## DIVISION 600 STRUCTURES



## SECTION 601 TIMBER STRUCTURES

**601.01 Description.** This work consists of furnishing, treating, and constructing timber structures of treated, untreated, and structural glue-laminated (glulam) timber.

**MATERIALS.**

**601.02 Structural Lumber and Timber.** The lumber and timber shall be dense quality long leaf or short leaf southern yellow pine or close-grained Douglas fir conforming to the requirements of AASHTO M 168. The grade of structural lumber and timber shall be as shown on the Plans. Unless otherwise specified, the timber shall be cut square and surfaced on four sides.

**601.03 Glue-Laminated Timber.**

a. *General.* Glulam lumber shall be kiln-dried Douglas fir or southern pine meeting the engineering properties, such as bending stress, shear, and modulus of elasticity, as stated on the Plans and the standards of ANSI/AITC A190.1. All members shall be bonded with an exterior "Wet-Use" adhesive conforming to Voluntary product Standard PS 56-73 of the U.S. Department of Commerce, NIST.

b. *Decks.* All milling and glue lamination shall be performed prior to treating. Planing shall be done on one side only. The top of the deck shall be left rough to ensure proper bonding with bituminous material.

   The deck panel manufacturer shall have experience in manufacturing glue-laminated wood bridge members, and a qualified licensee of the American Institute of Timber Construction (AITC).

c. *Members.* Glulam timber members manufactured for the Department's bridges shall bear a custom quality product mark as specified in ANSI/AITC A190.1. A certificate of material conformance shall be provided to the Engineer upon delivery of the member to the Project.

**601.04 Treatment.** Preservative treatment of timber shall conform to the requirements of Section 814 and the requirements of the AASHTO Standard Specifications for Highway Bridges

**601.05 Inspection.** The timber, and the operation of treatment, will be inspected at the treating plant, both before and after treating, and all acceptable timber will be marked with the Department's standard hammer mark. All timber shall also be subject to inspection at the site of the work. If the timber is found defective, it shall be subject to rejection.

**601.06 Structural Steel.** Structural steel shall conform to the requirements covering carbon shapes, plates, and bars of structural quality for use in the construction of bridges. Carbon shapes, plates, and bars shall be completely galvanized according to AASHTO M 111. Thickness Grade 85 shall be used. For further material requirements refer to Section 826.

**601.07 Hardware.** Machine bolts, drift pins, dowels, nuts, washers, lag screws, and nails shall conform to the requirements of ASTM A 307.

Machine bolts shall have square heads and nuts, unless otherwise specified. Nails shall be cut or round wire of standard form. Spikes shall be cut or wire spikes, or boat spikes, as specified.

Nails, spikes, bolts, dowels, washers, rods, plates, and lag screws shall be completely galvanized according to the requirements of AASHTO M 232.

For glulam timber, the fabricator shall provide all steel connections and all hardware for joining wood members to each other and to the substructure. All hardware shall be galvanized mild steel AASHTO M 270/M 270M. Washers may be cast iron or malleable iron.

**601.08 Working Drawings.** Working drawings shall be submitted in accordance with Subsection 105.04.

**CONSTRUCTION METHODS.**

**601.09 Storing and Handling.** All lumber and timber on the site of the work shall be stacked to prevent warping. Untreated material shall be open stacked at least 12" (300 mm) above the ground surface, and so piled as to shed water. Material shall be protected from the weather by suitable covering. Treated timber shall be carefully handled, without sudden dropping, breaking of outer fibers, bruising, or penetrating the surface with tools. Treated timber, other than piling, shall be handled with rope slings. Canthooks, peaveys, pikepoles, or hooks shall not be used. Treated timber shall be close stacked. The ground under and in the vicinity of all stacks shall be cleared of weeds and rubbish.

All bridge lumber shall be delivered and stored above grade on wooden blocks. Members shall be well supported and be leveled to avoid warping. When stacking, measures shall be taken to permit air to circulate around all four sides of each member.

**601.10 Workmanship.** All framing shall be true and exact. Unless otherwise specified, heads of nails and spikes shall be driven flush with the surface of the wood. Deep hammer marks in wood surfaces, splitting due to nailing, or spiking shall be considered evidence of poor quality of work and will be sufficient cause for removal of the workers causing them.

**601.11 Cutting and Framing.** All lumber and timber shall be accurately cut and framed to a close fit in such a manner that the joints have an even bearing over all contact surfaces. No shimming will be permitted in making joints, nor will open joints be accepted. All cutting and framing of treated timber shall be done before treatment insofar as is practicable.

All cuts and abrasions in creosote treated timbers glulam timber shall be treated shall be carefully trimmed, and then covered with two applications of a mixture of 60% creosote oil and 40% roofing pitch, or brush coated with at least two applications of hot creosote oil and covered with hot roofing pitch. The creosote oil shall be heated sufficiently to secure deep penetration but shall not be heated to the boiling point.

All cuts and abrasions in CCA treated timbers shall receive one brush application of the CCA solution used in the treatment process.

**601.12 Holes for Bolts, Dowels, Rods, and Lag Screws.** Bolt holes shall be treated with creosote oil-tar or CCA solution as applicable, by means of an approved device that applies the creosote oil-tar or CCA solution to the inside of the hole. Any unfilled holes shall be treated in the same manner and then shall be plugged with creosoted or CCA treated plugs.

Holes for round driftbolts or dowels shall be bored with a bit 1/16" (1.6 mm) less in diameter than the bolt or dowel to be used. The diameter of the holes for square driftbolts or dowels shall be equal to the least dimension of the bolt or dowel.

Holes for machine bolts shall be bored with a bit of the same diameter as the bolt.

Holes for lag screws shall be bored with a bit not larger than the body of the screw at the base of the thread.

A washer, of the size and type specified, shall be used under all bolt heads and nuts which would otherwise come in contact with the wood.

All bolts shall be thoroughly checked after the nuts have been finally tightened.

**601.13 Countersinking.** Countersinking shall be done wherever smooth faces are required. Recesses formed for countersinking shall be treated with material as specified in Subsection 601.12 and as approved by the Engineer.

**601.14 Caps.** Timber caps shall be placed to secure an even and uniform bearing over the tops of the supporting posts or piles and to secure an even alignment of their ends. All pile caps shall be secured in the manner shown on the Plans.

**601.15 Bracing.** The ends of bracing shall be bolted through the pile, post, or cap as shown on the Plans. Intermediate intersections shall be bolted as shown on the Plans.

**601.16 Stringers.** Stringers shall be sized at bearings and shall be placed in position so that knots near edges are in the top portion of the stringers, except over continuous supports.

Outside stringers may have butt joints, but interior stringers shall be lapped to take bearings over the full width of the floor beam or cap at each end.

Cross-bridging between stringers shall be neatly and accurately framed and securely toenailed with at least two nails in each end.

**601.17 Method of Measurement.** The quantity of structural lumber and timber will be measured by the thousand feet, board measure (cubic meter). The quantity will be determined from actual widths and thicknesses and the actual lengths of the pieces in the finished and accepted structure.

The quantity of glue-laminated timber deck will be measured by the square foot (square meter). The quantity will be determined from the actual length and width of the finished deck completed and accepted.

The quantity of glue-laminated timber used for other members of the structure as specified on the Plans will be measured by the thousand feet, board measure (cubic meter).

**601.18 Basis of Payment.** The quantity of timber will be paid for at the Contract unit price per thousand feet, board measure (cubic meter). Price and payment will constitute full compensation for furnishing all materials; for applying preservative treatment when required; for placing all material including hardware; for the replacement of all defective materials; and for all labor, equipment, tools, and incidentals required to complete the work.

The quantity of glue-laminated timber deck will be paid for at the Contract unit price per square foot (square meter). The quantity of glue-laminated timber used for other members of the structure will be paid for at the Contract unit price per thousand feet, board measure (cubic meter). Price and payment will constitute full compensation for furnishing and placing all materials, including hardware; for fabricating glue-laminated timber decks and members; for applying preservative treatment; and for all labor, equipment, tools, and incidentals required to complete the work.

## SECTION 602 CONCRETE STRUCTURES

**602.01 Description.** This work consists of furnishing and placing portland cement concrete for structures and incidental construction.

### MATERIALS.

**602.02 Materials.** Materials for concrete structures shall conform to the following Section and Subsections:

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| Materials for Sealing Joints: | |
| Preformed Elastomeric Compression Seals | 808 |
| Rubber Joint Sealant | 808 |
| Hot Poured Joint Sealer | 808 |
| Preformed Expansion Joint Fillers, Type III | 808 |
| Portland Cement Concrete | 812.02 |
| Chemical Admixtures | 812.02 |
| Curing Materials: | |
| Liquid Membrane Compounds | 812.02 |
| Polyethylene Sheeting | 812.02 |
| Waterproof Paper | 812.02 |
| Mix Composition, Classes A, B, C, and D | 812.04 |
| Bar Reinforcement | 824.01 |
| Bar Reinforcement, Epoxy Coated | 824.02 |

**602.03 Permanent Steel Bridge Deck Forms and Supports.** Permanent steel bridge deck forms and supports shall be fabricated from steel conforming to ASTM A 653/A 653M Grade 40 for 14-18 gage, Grade 80 for 19-22 gage and Grade 40 for accessories, and shall have a coating of Z600 according to ASTM A 924/A 924M. Deck forms shall be 20 gage (0.9 mm) minimum.

**602.04 Pipe For Weep Holes.** Cast iron soil pipe for weep holes shall conform to the requirements of ASTM A 74. Plastic pipe shall conform to the requirements of ASTM D 2665.

**602.05 Waterstops.** Sheet copper shall conform to the requirements of ASTM B 370. Sheet lead shall conform to the requirements of ASTM B 29. Sheet zinc shall conform to the requirements of ASTM B 69.

**602.06 Form Oil For Concrete Formwork.** Form oil shall be a non-staining petroleum distillate free from water, asphaltic, and other insoluble residue or equivalent product.

**602.07 Waterstops.** Waterstops shall be polyvinyl chloride (PVC) compounded as necessary to conform to the requirements of U.S. Army Corps of Engineers Specification CDR-C572. No reclaimed PVC from any sources shall be incorporated in the compounding. The extruded material shall be dense, homogeneous, and free from porosity or other imperfections that could affect its durability or performance.

**CONSTRUCTION METHODS.**

**602.08 Formwork.** Except where indicated elsewhere in this Section, forms shall be designed and constructed so they can be removed without injuring the concrete. Forms shall be designed for strength and deflection to resist all loads and pressures of the wet concrete, the weight of the forms, the rate of pour, the affect of vibration, the time of setting, and an addition of 50 lb/ft$^5$ (2.4 kPa) of construction live load applied to all horizontal surfaces. For removable forms, no member shall have a deflection, under total load, in excess of 1/360 of its span length, and in no case shall the deflection exceed $3$" (6 mm), except that deflections of form surfaces for concrete floor slabs where such forms are supported by beams, stringers, or girders may be 1/180 of the span length but not to exceed $2$" (13 mm). Where the design of the forms requires deflections in excess of these amounts, the forms shall be cambered.

Concrete shall be assumed to weigh 150 lb/ft; (2400 kg/m$^3$). Lumber in forms shall be assumed to weigh 4lb per board foot (700 kg/m$^3$). For all other materials, other than lumber in forms, the unit weight of the material shall be used.

Formwork plywood (without backing) shall be used with the face plies running parallel to the span (or perpendicular to supports) for maximum working strength and minimum deflection.

The Contractor shall prepare and submit for approval complete detailed plans of all formwork to be constructed. Working formwork drawings shall be submitted in accordance with Subsection 105.04. The Contractor shall not proceed with formwork construction until its plans have been approved. However, approval of these plans shall not relieve the Contractor of complete responsibility for the safety and adequacy of all formwork.

The form drawings shall show all major design values and loading conditions. These include assumed values of live and dead load, rate of placement, temperature of concrete, height of drop, weight of moving equipment which may be operating on formwork, foundation pressures, design stresses, deflection and camber diagrams, and other pertinent applicable information. All pertinent design calculations shall be submitted for walls greater than 10' (3 m) in height. In addition to specifying types of materials, sizes, lengths, and connection details, formwork drawings shall provide for applicable details such as: 1) Anchors, shores, and braces; 2) field adjustment of the form during placing of concrete; 3) waterstops, keyways and inserts; 4) working scaffolds and runways; 5) weepholes or vibrated holes where required; 6) screed and grade strips; 7) crush plates or wrecking plates; 8) removal of spreaders or temporary blocking; 9) cleanout holes; 10) construction, control and expansion joints; 11) chamfer strips; 12) notes to cover conduits and pipes to be embedded; and 13) details on shoring, re-shoring, or leaving original shores in place as forms are stripped.

The material to be used for forms for exposed surfaces shall be either plywood, metal in which all bolts and rivet holes are countersunk, fiber, or other approved material. In either case, a plain, smooth surface of the desired contour must be obtained. For surfaces to be given a rubbed finish, the material shall be plywood unless otherwise specifically approved. For curved or special surfaces, the above requirements may be modified.

The form material shall be placed so a smooth surface free from irregularities is obtained. Sheets of material shall be placed so that joints are in regular and true horizontal and vertical lines. Full sized plywood sheets shall be used except where a single smaller piece covers an entire area. Where form lining is used, it shall be used in pieces as large as possible. All joints shall be solidly backed, butted tightly together, and sealed with white lead paste or other approved crack fillers. All holes shall be filled as well as depressions or hammer marks so that the completed surface is as smooth as possible. When steel forms are used, the panels shall be as large as practical and of sufficient thickness to prevent surface irregularities. Panels shall be assembled in uniform patterns and firmly locked and braced together to form a smooth surface. Bent or irregular panels shall not be used. Round fiber column forms shall be furnished full height and shall be fitted with circular wooden templates at top and bottom and with wooden collars at intermediate points. Fiber forms shall be removed not later than ten days after pouring.

Moldings, fluting, rustification, and other ornamental details shall be formed of material specifically manufactured for the job. Samples or details of the material shall be submitted for approval by the Engineer prior to use.

All lumber shall be free from knotholes, loose knots, cracks, splits, warps, or other defects impairing the strength or the appearance of the finished structure.

When necessary because of thin wall construction, forms shall be daylighted at intervals not greater than 10' (3 m) vertically, the openings being sufficient to permit free access to the forms for the purpose of inspecting, working, and vibrating the concrete.

The forms shall be built true to line and braced in a substantial and unyielding manner. They shall be mortar tight and, to close cracks due to shrinkage, shall be thoroughly soaked with water.

Dimensions affecting the construction of subsequent portions of the work shall be carefully checked after the forms are erected and before any concrete is placed. The interior surfaces of the forms shall be adequately oiled, greased, or soaped to ensure non-adhesion of mortar. Form plywood and/or lumber which is reused shall be free from bulge, warp or damage and shall be thoroughly cleaned. The forms shall be inspected immediately preceding the placing of concrete and any defects shall be remedied and all dirt, sawdust, shavings, or other debris within the forms shall be removed.
Blocks and bracing shall be removed with the forms and in no case shall any portion of the wood forms be left in the concrete. Special attention shall be paid to the ties and bracing and when forms appear to be insufficiently braced or unsatisfactorily built, either before or during construction, the work will be ordered stopped until the defects have been corrected. The forms shall be so constructed that the finished concrete shall be of the form and dimensions shown on the Plans and true to line and grade.
On the structures having cement concrete masonry decks, supported by beams and girders, the forms for the deck slabs shall be so constructed that under full dead load, the slabs will be of the required thickness shown on the Plans and the surface of the roadway will accurately conform to the profile grades, cross-sections and alignments as shown on the Plans. Allowance shall be made for the camber of the beams and stringers as fabricated and erected and also for the additional

deflections due to dead load. The depth of haunches between the top of the stringers and the bottom of the slab as shown on the Plans, is theoretical, and due to variations in obtainable camber in the stringers and to usual inaccuracies of fabrication and erection, the depths of haunches to be constructed may vary considerably from the theoretical. The formwork shall be constructed so as to provide for any and all necessary variations in actual depths of haunches required.

**602.09 Falsework.** Falsework shall be designed in accordance with FHWA-RD-93-032, dated November 1993. Falsework shall be designed to be built on a firm foundation and to carry the anticipated loads without appreciable deflections as specified in Subsection 602.08 for formwork. It shall be constructed so as to provide the camber shown on the Plans for the completed structure. Proper allowance shall be made for take-up in timbers and probable falsework settlement. A "telltale" or other approved type indicator shall be attached to the forms in a manner to indicate any settlement, movement or deflections in the forms or falsework. If any of them is in excess of the prescribed tolerance(s), the work shall be stopped and the Contractor shall be required to rectify the problem to the full satisfaction of the Engineer.

The Contractor shall engage a Professional Engineer registered in Delaware to design the falsework separately for every bridge on the Project. The Professional Engineer's signature and seal shall be affixed to the working drawings. Working falsework drawings shall be submitted in accordance with Subsection 105.04. It is the Contractor's responsibility to obtain approval of the working drawings from the Department prior to the construction of the falsework. Such approval, when given by the Department, shall not relieve the Contractor from the responsibility for the adequacy and satisfactory performance of the falsework.

Falsework systems shall be designed to handle all vertical and horizontal loadings and should contain enough redundancy to prevent a failure in the entire system. Vertical loading and differential settlement forces, and horizontal lateral and longitudinal forces shall also be taken into account for design of the falsework.

After placement of the falsework, the Contractor's Professional Engineer shall certify that the falsework system has been assembled according to the approved falsework drawing prior to placing loads on the falsework. When falsework installations are to be erected adjacent to a highway, special design consideration and protection shall be taken to ensure that falsework system is not disturbed by errant highway vehicles or by the vibration forces caused by the passing vehicles.

In the event falsework is moved from one bridge to another, the falsework shall be thoroughly inspected for structural damage and plumbness and approved by the Contractor's Professional Engineer prior to its use to ensure that all members are in place and properly aligned and connected.

**602.10 Placing Concrete.** No concrete shall be placed until the depth of the excavation and character of the foundation material, the adequacy of the forms and falsework, and the placing of reinforcement and other embedded items have been inspected and approved by the Engineer.

Concrete shall be placed in daylight unless an adequate lighting system meeting the approval of the Engineer is provided.

In preparation for the placing of concrete, all sawdust, chips, and other construction debris and extraneous matter shall be removed from the interior of forms. Hardened concrete and foreign matter shall be removed from tools, screeds, and conveying equipment.

The temperature of the concrete shall not be greater than 90 EF (32 EC), nor less than 50 EF (10 EC) at the time of placing, except where other temperatures are required in this Section. The temperature of concrete for bridge decks shall not exceed 85 EF (29 EC). During hot weather, the Contractor may be required to chill the mixing water, incorporate ice into the concrete mixture as part of the mixing water, or take other measures as prescribed in Section 812 to maintain concrete temperatures below the specified maximum temperatures. In addition, any combination of wind velocity, high air temperatures and low relative humidity, which, in the opinion of the Engineer, will impair the quality of fresh or hardened concrete due to rapid concrete moisture evaporation shall be sufficient cause to discontinue or prohibit concrete placement. The ACI Recommended Practice for Hot Weather Concreting will be used as a guide in assessing the hazards of hot weather.

No concrete shall be used which does not reach its final position in the forms within the time stipulated in Subsection 812.06.

Surfaces other than foundations on which concrete is to be placed shall be thoroughly cleaned and wetted immediately before placing concrete in order to facilitate bonding.

Placing of concrete shall be so regulated that the pressures caused by the wet concrete shall not exceed those used in the design of the forms.

The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. During the placing of concrete, care shall be taken that the methods of compaction used will result in a surface of even texture free from voids, water, or air pockets, and that the coarse aggregate is forced away from the forms in order to leave a mortar surface.

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete may be placed with the aid of buckets, chutes, troughs, pipes, or conveyors. Open troughs or chutes shall be metal or metal lined and extend as nearly as possible to the point of deposit. Aluminum will not be permitted as the contact surface for concrete placed through any conveyance.

Chutes on steep slopes shall be equipped with baffle boards or be in short lengths that reverse the direction of concrete movement. Chutes shall not slope greater than 1:2 (vertical to horizontal) or less than 1:3 (vertical to horizontal). Concrete placed with chutes over 25' (7.6 m) long or not meeting these slope standards shall discharge into a hopper before distribution unless otherwise directed.

All chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the structure.

Dropping the concrete a distance of more than 5' (1.5 m) or depositing a large quantity at any point and running or working it along the forms will not be permitted, except that the 5' (1.5 m) limitation will not apply to the dropping of concrete into the forms for the walls of box culverts, or retaining walls unless directed by the Engineer.

Care shall be taken to fill each part of the form by depositing the concrete as near its final position as possible. The coarse aggregate shall be worked back from the forms and worked around the reinforcement without displacing the bars. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the projecting reinforcement or other items embedded in the concrete, except where unavoidable on structures being widened under traffic.

Concrete shall be placed in continuous horizontal layers, the thickness of which generally shall not exceed 10 to 12" (250 to 300 mm). However, slabs shall be placed in a single layer. When it is necessary in an emergency to place less than a complete horizontal layer in one operation, such layer shall terminate in a vertical bulkhead. In any given layer, the separate batches shall follow each other so closely that each one shall be placed and consolidated before the preceding one has taken initial set in order that the fresh concrete shall not be injured and there shall be no lines of separation between the batches. Each layer of concrete shall generally be left somewhat rough to secure efficient bonding with the next layer above. A succeeding layer placed before the underlying layer has become set shall be consolidated in a manner that will entirely break up and obliterate the tendency to produce a construction joint between the layers.

Layers completing a day's work or placed prior to temporarily discontinuing operations shall be cleaned of all laitance and other objectionable material as soon as the surface has become sufficiently firm to retain its form. To avoid visible joints as far as possible upon exposed faces, the top surface of the concrete adjacent to the forms shall be finished being smoothed with a trowel.

Horizontal layers so located as to produce a construction joint at a location wherein a feather edge might be produced in the succeeding layer shall be so formed by inset formwork that the succeeding layer will end in a body of concrete having a thickness of not less than 6" (150 mm).

In no case shall the work on any section or layer be stopped or temporarily discontinued within 18" (450 mm) of the top of any face, unless the details of the work provide for a coping having a thickness of less than 18" (450 mm) in which case at the option of the Engineer, the construction joint may be made at the underside of the coping.

Care shall be exercised during the placement of concrete to minimize the coating of reinforcing steel, structural steel, forms, and other items which extend into areas involved in a subsequent placement. In the event coating of the steel does occur, no attempt shall be made to remove the mortar until after the concrete steel bond of the earlier placement has developed sufficiently to withstand a cleaning operation. Any coating of mortar on deformed bars which cannot be removed by hand brushing with a wire bristle brush, or by a light chipping action, will not have to be removed.

The method and manner of placing concrete shall be so regulated as to place all construction joints across regions of low shearing stress and in such locations as will be hidden from view to the greatest possible extent.

The operations of depositing and consolidating the concrete shall, in general, be conducted so as to form a compact, dense, impervious mass of uniform texture which will show smooth faces on exposed surfaces. Any section of concrete found to be defective shall be removed or repaired as directed by the Engineer.

If concrete operations are permitted to extend into the night, the work shall be brightly lighted so that all operations are plainly visible. Lighting requirements are indicated in Subsection 602.24.

**602.11 Placing Concrete During Cold Weather.** The following requirements shall govern the placing of concrete during cold weather:

a. *General.* No concrete shall be placed when the air temperature, measured at the location of the concreting operation in the shade away from artificial heat, is below 35 ºF (2 ºC) without permi ssion of the Engineer. The temperature of the concrete shall not be less than 55 ºF (13 ºC) and not more than 80 ºF (27ºC) at the time it is placed in the forms.

   The aggregates shall be free from ice, frost, and frozen particles, and concrete shall not be placed on frozen foundation material.

   The Contractor shall protect all concrete by means of heated enclosures or by insulation whenever any of the following conditions occur:

   1. The concrete has been placed when the air temperature, measured at the location of the concreting operation in the shade away from artificial heat, is below 35 ºF (2 ºC).
   2. The air temperature, measured at the location of the freshly placed concrete in the shade away from artificial heat, is below 35 ºF (2 ºC) and the concrete has not yet attained an age of 72 hours.

      The Contractor shall provide and place at locations directed by the Engineer a sufficient number of maximum-minimum recording thermometers to provide an accurate record of the temperature surrounding the concrete during the entire protection period.

      The Contractor shall assume all risks connected with the placing of concrete under the cold weather conditions referred to herein. Permission given by the Engineer to place concrete when the temperature is below 35 ºF (2 ºC) and the subsequent protection of the concrete as required herein shall not relieve the Contractor in any way of the responsibility for obtaining the required results.

b. *Heated Enclosures.* Portland cement concrete, that is placed when the air temperature is below 35 ºF (2 ºC) and portland cement concrete that has not yet attained an age of 72 hours before the air temperature falls below 35 ºF (2 ºC), shall be immediately enclosed with a housing consisting of canvas or other approved material supported by an open framework or with an equally satisfactory housing, and the air surrounding the concrete shall be maintained at a temperature of not less than 50 ºF (10 ºC) nor more than 70 ºF (21 ºC) for the remainder of the 72-hour period. The air surrounding the concrete shall be maintained at temperatures above 32 ºF (0 ºC) for not less than 48 hours immediately thereafter. The time periods referred to above shall not begin until the manipulation of each separate mass of concrete has been completed.

   The Contractor shall provide such heating apparatus as stoves, salamanders, or steam equipment, and the necessary fuel. When dry heat is used, means of preventing loss of moisture from the concrete shall be provided.

c. *Insulation.* Protection of concrete by the use of approved insulated forms or insulation blankets will be permitted in lieu of the heated enclosure. Insulation will be required under the same conditions that heated enclosures are required, and shall be placed on the concrete as soon as initial set will permit.

Insulating materials shall have a minimum thickness of 1" (25 mm). The thermal conductivity ("k" factor) of the insulation shall not exceed 0.27 BTU per hour square foot (0.85 W/$m^2$) for a thermal gradient of one degree F per inch (0.02 ºC/mm) as determined by ASTM C 177. Results of tests conducted in accordance with ASTM C 177 by an acceptable commercial testing laboratory shall be furnished to the Engineer for approval. Such approval shall be secured prior to use of the material. Insulating blankets shall be faced or covered, top and bottom, with polyethylene or similar waterproofing material. Blankets shall be placed on the concrete in such a manner that they form a waterproof surface for the concrete being protected. When the anticipated low temperature expected to occur during the protection period is lower than 10 ºF (-12 ºC), 2" (50 mm) of insulation will be required.

Blanket insulation mats shall overlap at the edges by at least 6" (150 mm). Rigid type insulation sheets shall be tightly butted together and sealed. Particular care shall be taken to provide effective protection of curbs, corners, and around protruding reinforcing steel. Overhang forms shall be insulated both on the outside vertical faces and on the underside with a 1" (25 mm) minimum thickness of either rigid or blanket type insulation.

Should the air under the insulation fall below 50 ºF (10 ºC) during the protection period, the Contractor will be required to immediately cover the concrete with canvas and framework or other satisfactory housing and apply heat uniformly at a rate such that the air surrounding the concrete is not less than 50 ºF (10 ºC) for the remainder of the protection period.

**602.12 Pumping Concrete.** Placement of concrete by pumping will be permitted only when approved by the Engineer. Prior to starting the pumping operation, the Contractor shall also get a method approved by the Engineer for maintaining continuous placement of concrete in case of breakdown of the concrete pump. Pumping equipment shall be located so that no vibrations result which might damage the freshly placed concrete. Pumping equipment, including the conduit system, shall not contain any aluminum or aluminum alloy in contact with the concrete. The conduit system shall consist of 5" (125 mm) minimum inside diameter rigid or flexible pipe.

Grout used to lubricate the inner surfaces of the conduit system shall be wasted.

Operation of the pump shall be such that a continuous stream of concrete without air pockets is delivered. When pumping is completed, any concrete remaining in the pipeline which is to be used in the work shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients.

Samples of concrete to be used for test purposes shall be taken from the discharge end of the conduit system and shall be taken as close as possible to the final position of the concrete.

**602.13 Consolidation of Concrete by Vibration.** Concrete, except that placed under water, or as otherwise approved, shall be compacted during and immediately after depositing by means of approved mechanical vibrating equipment.

Internal mechanical vibrators shall be of sturdy construction, with a cutoff switch at the vibrator, adequately powered and capable of transmitting vibrations to the concrete in frequencies of not less than 5000 impulses per minute and shall produce a vibration of sufficient intensity and amplitude to cause settlement of the concrete into place without a separation of the aggregates.

In using internal vibrators, the vibratory element shall be inserted into the concrete at the point of deposit and in the areas of freshly-placed concrete. The time of vibration shall be long enough to accomplish thorough consolidation of the concrete and complete embedment of the reinforcement, to produce a smooth surface free from honeycombing and air bubbles, and to work the concrete into all angles and corners of the forms. However, over-vibrating shall be avoided. Vibration shall continue in a spot only until the concrete has become plastic and shall not continue to the extent that pools of grout are formed. The correct length of time of vibration will depend upon the frequency of the vibration impulses per minute, the size of vibrators and the slump of the concrete.

Internal vibrators shall be applied at points uniformly spaced, not farther than the radius over which the vibration is visibly effective and shall be applied close enough to the forms to effectively vibrate the surface concrete. The vibration shall not be dissipated in lateral motion but shall be concentrated in vertical settlement in consolidating the concrete. Vibrators shall not be used to move concrete.

The vibrating element shall be inserted in the concrete mass a sufficient depth to vibrate the bottom of each layer effectively and in as nearly a vertical position as practicable. It shall be withdrawn completely from the concrete before being advanced to the next point of application.

To secure an even and dense surface free from aggregate pockets or honeycomb, vibration shall be supplemented by working or spading by hand in the corners or angles of the forms and along form surface while the concrete is plastic under the vibratory action.

A sufficient number of vibrators shall be employed so that at the required rate of placement thorough consolidation is secured throughout the entire volume of each layer of concrete. Extra vibrators shall be on hand for emergency use and for use when other vibrators are being serviced.

The use of surface vibrators to supplement internal vibration will be permitted only when satisfactory surfaces cannot be obtained by internal vibration alone, and only upon approval. Surface vibrators shall be applied only long enough to embed the coarse aggregate and to bring enough mortar to the surface for satisfactory finishing.

The use of approved form vibrators will be permitted only when it is impossible to use internal or surface vibrators. When permitted, they shall be attached to or held on the forms in such manner as to effectively transmit the vibration to the concrete and so that the principal paths or motions of the vibration are in a horizontal plane.

**602.14 Joints.**

a. *Construction Joints.* Construction joints shall be made only where located on the Plans or shown in the placing schedule, unless otherwise approved by the Engineer.

   If not detailed on the Plans, or in the case of emergency, construction joints shall be placed as directed by the Engineer. Shear keys or inclined reinforcement shall be used where necessary to transmit shear or bond the two sections together. Joints shall be so constructed that feather edging does not occur.

   For construction joints in deck slabs, a 2 by 1$\frac{1}{2}$" (50 by 38 mm) shear key shall be provided between the mats of reinforcing steel.

   In construction joints exposed to view or in other construction joints where seepage of water is particularly objectionable, or where specified on the Plans, an approved waterstop shall be inserted. The waterstop shall be placed not less than 3" (75 mm) from the face of the concrete and shall extend into each section of the concrete a distance of not less than 2" (50 mm) or as specified on the Plans.

   When longitudinal joints are specified or permitted, they shall be spaced so that each placement of concrete is not less than 10' (3 m) in width. Transverse joints shall be placed at the centerlines of piers or as specified on the Plans. Concrete shall be placed in one continuous operation between construction joints. The minimum volume of concrete in any one placement shall be not less than the volume of concrete in one end span. The falsework under all spans from edge to edge of slab or from edge of the slab to an open joint shall remain in place until the concrete in the entire slab has attained the minimum 28-day design compressive strength required for the mix.

b. *Bonded Construction Joints.* If joining fresh concrete to concrete that has already set, the work already in place shall have its surface roughened thoroughly with a suitable tool and all shavings, sawdust or other loose and foreign material shall be removed. The surface shall be washed and scrubbed with wire brooms when necessary to remove substances that may interfere with the bond. The concrete of the preceding placement shall be thoroughly wetted prior to the placement of the next unit of fresh concrete.

   For construction joints in deck slabs, the vertical face shall be epoxy coated prior to placement of adjoining concrete with epoxy bonding compound.

   In order to bond successive courses, suitable keys shall be formed at the top of the upper layer of each day's work and at other levels where work is interrupted. These keys shall be formed by the insertion and subsequent removal of beveled wood strips which shall be saturated thoroughly with water to induce swell prior to insertion in the fresh concrete. Rough stone or steel dowels may, at the discretion of the Engineer, be used in lieu of keys. Dowels shall extend an equal distance on each side of the construction joint. Prior to inserting or driving of dowels into predrilled or preformed holes, the holes shall be filled with portland cement grout in the proportion of one part cement to two parts sand. The size and spacing of keys and dowels shall be determined by the Engineer.

When bonding fresh concrete to hardened concrete, or hardened concrete or steel to hardened concrete, an epoxy bonding compound conforming to AASHTO M 235 shall be used. Surface preparation, mixing and application requirements, and limitations as specified by the manufacturer shall be strictly followed. Bonding compounds shall be approved prior to use.

The Contractor shall schedule its concreting operations so that the concrete is placed while the epoxy bonding compound is still uncured and tacky. If, in the opinion of the Engineer, the bonding compound has begun to cure, no concrete shall be placed until a new film of bonding compound has been applied to the required areas.

c. *Expansion Joints.* Expansion joints shall be provided as shown on the Plans. They shall be made by building keyed faces and are to be covered with bituminous expansion felt or other approved material to prevent leakage and the adhesion of the concrete faces. Roofing paper will not be considered as expansion material.

**602.15 Joint Sealants.** Sealant type shall be as specified on the Plans.

a. *Rubber Joint Sealant.* A primer shall be used as recommended by the sealant manufacturer. A bond breaker such as masking tape, polyethylene film, or backing rod as supplied by the manufacturer shall be used at the bottom of the joint.

The surfaces of the joints or recesses must be clean and dry, and free of corrosion, scale, rust, oil, wax, tar, paint, and other contamination. Masonry joints shall be sandblasted to remove contamination. Metal surfaces shall be given a commercial sandblast.

Masking tape shall be applied along the edges of joints where required. Joint faces shall be primed in accordance with sealant manufacturer's instructions. Sealant shall be placed following the manufacturer's instructions regarding mixing and application. Sealant shall not be applied on wet or frosty surfaces or when the surface temperatures are below 40 ºF (4 ºC) or above 130 ºF (55 ºC). Adjacent surface shall be cleaned free of sealant with mechanical action or solvent as necessary. Finished work shall be left in a neat and clean condition.

b. *Bituminous Joint Sealant.* Bituminous joint sealant shall be hot applied or cold applied elastomeric sealant.

**602.16 Waterstops.** The size and configuration of waterstop shall be as shown on the Plans. Waterstop should preferably be spliced only at joints made necessary by construction design. All joints shall be made in strict accordance with the procedures recommended by the manufacturer. No appreciable loss in strength, elasticity, or durability shall result at splices.

Plastic waterstop shall be carefully placed at the locations shown on the Plans or as directed. A split form technique shall be used during installation. Bending of the waterstop along the face of form shall not be permitted. Precautions shall be taken that the waterstop shall neither be displaced nor damaged by construction operations or other means. All surfaces of the waterstop shall be free from oil, grease, dried mortar, or other foreign matter while the waterstop is being embedded in concrete. Means shall be used to ensure that all portions of the waterstop designed for embedment are tightly enclosed by dense concrete.

If requesting approval of a waterstop, the Contractor shall furnish a 12" (300 mm) length of the extruded section of waterstop that it intends to supply, with a certification that the material conforms to all requirements of this Subsection.

**602.17 Finishing Concrete Surfaces.**

a. *General.* All concrete surfaces shall be true, even, and free from open or rough places, depressions, or projections. The concrete in all bridge seats, parapets, sidewalks, curbs, railings, and walls shall be brought flush with the finished top surface and shall be struck off with a template and floated to a finish free from irregularities and true to line and grade.

All masonry bearing areas as prescribed in Subsection 605.29 shall be placed to the final elevation specified. They shall be bush-hammered down to within 3" (6 mm) of the final elevation and ground with an approved device to a smooth, level, true plain surface which must be within 1/8" (3 mm) of the prescribed bearing elevation. The concrete in the bearing area shall be poured high enough so that no part of the bearing area, after bush-hammering, is lower than the surrounding bridge seating surface.

Unless otherwise specified on the Plans, all surfaces shall be given an ordinary surface finish unless after form removal they are in such a condition that they cannot be repaired to the satisfaction of the Engineer. In these cases, the entire structural unit shall be given a rubbed finish.

b. *Ordinary Surface Finish.* Immediately following the removal of the forms, all fins and irregular projections shall be removed from all surfaces except from those which are not to be exposed or are not to be water-proofed. On all surfaces, the cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects shall be thoroughly cleaned, saturated with water, and carefully pointed and trued with a mortar of cement and fine aggregate mixed in the proportions used in the grade of the concrete being finished. Mortar used in pointing shall be not more than 30 minutes old. The mortar patches shall be cured as specified in Subsection 602.18. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

c. *Rubbed Surface Finish.* After removal of forms, the rubbing of concrete shall be started as soon as its condition permits. Immediately before starting this work, the concrete shall be kept thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing to thoroughly set. The surface to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand mixed in proportions used in the concrete being finished. Rubbing shall be continued until all form marks, projections, and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

   After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

   After the final rubbing is completed and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

d. *Float Finish.* This finish, for horizontal surfaces, shall be achieved by placing an excess of material in the form and removing or striking-off the excess with a template, forcing the coarse aggregate below the mortar surface. Creation of a concave surface shall be avoided. After the concrete has been struck off, the surface shall be thoroughly worked and floated with a suitable wood, canvas, or cork floating tool. Before the finish has set, the surface cement film shall be removed with a fine brush in order to have a fine grained, smooth but sanded texture.

e. *Special Surface Finish.* As an alternative to the rubbed surface finish, an acrylic or latex bonded mortar finish may be used when and where designated in the Plans and Special Provisions.

f. *Tooled Finish.* A tooled finish shall be made on the surfaces previously spaded by cutting into the body of the concrete with a pointing tool or bush-hammer as indicated on the Plans.

**602.18 Curing.** All exposed surfaces shall be cured by one of the following methods:

a. *Water Methods.* The concrete shall be kept continuously wet by the application of water for a minimum period of seven curing days after the concrete has been placed.

   When cotton mats, burlap, or earth or sand blankets are to be used to retain the moisture, the entire surface of the concrete shall be kept damp by applying water with a nozzle that so atomizes the flow that a mist and not a spray is formed, until the surface of the concrete is covered with the curing medium. The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface. At the expiration of the curing period, the concrete surface shall be cleared of all curing mediums.

b. *Membrane Curing Compound Method.* The entire surface of the concrete shall be sprayed uniformly with a liquid membrane curing compound conforming to the requirements of Subsection 812.02.

   The membrane curing compound shall be applied after the surface finishing has been completed, and immediately after the free surface moisture has disappeared.

The surface shall be sealed with a single uniform coating of the specified type of curing compound applied at the rate of coverage recommended by the manufacturer or as directed by the Engineer, but not less than 1 gal/150 ft5 (0.27 L/$m^2$) of area.

At the time of use, the compound shall be in a thoroughly mixed condition with the pigment uniformly dispersed throughout the vehicle. If the application of the compound does not result in satisfactory coverage, the method shall be stopped and water curing, as set out above, applied until the cause of the defective work is corrected.

At locations where the coating shows discontinuities, pinholes, or other defects, or if rain falls on the newly coated surface before the film has dried sufficiently to resist damage, an additional coat of the compound shall be applied immediately after the rain has stopped at the same rate specified herein.

Any curing compound adhering to a surface to which new concrete is to be bonded shall be completely removed by sandblasting, steel wire brushes, bush-hammers, or other approved means.

The concrete surfaces to which the compound has been applied shall be protected from abrasion or other damage which results in perforation of the membrane film for seven curing days after the concrete is placed. If the film of membrane compound is damaged or removed before the expiration of seven curing days, the exposed concrete shall be immediately cured by the water method until additional compound is applied or until seven curing days have expired.

In the event that the application of curing compound is delayed, the application of water shall be started immediately and shall be continued until application of the compound is resumed or started.

c. *Waterproof Sheeting Method.* The exposed finished surface of concrete shall be wetted with water, using a nozzle that so atomizes the flow that a mist and not a spray is formed, until the concrete has set, after which the waterproof sheeting shall be placed. Curing shall continue for seven curing days after the concrete has been placed. If the sheeting is damaged or removed before the expiration of seven curing days, the exposed concrete shall be immediately cured by the water method until additional sheeting is placed or until seven curing days have expired.

   Waterproof sheeting shall consist of paper or polyethylene conforming to the requirements of Subsection 812.02. The waterproof sheeting shall provide a complete continuous cover of the entire concrete surface. Sheets shall lap a minimum of 12" (300 mm) and shall be securely weighed down or cemented together in such a manner as to provide a waterproof joint.

   Should any portion of the sheets be broken or damaged before the expiration of the curing period, the broken or damaged portions shall be immediately repaired with new sheets properly cemented in place.

   Sections of sheeting which have been damaged to such an extent as to render them unfit for curing the concrete shall not be used

d. *Forms-In-Place Method.* Formed surfaces of concrete shall be cured by retaining the forms in place for a minimum period of seven days after the concrete has been placed. If the Contractor elects to leave forms in place for a part of the curing period and use one of the other methods of curing included in this article for the remainder of the curing period, the concrete surfaces shall be kept wet during the time the curing methods are being changed.

**602.19 Removal of Forms and Falsework, and Placement of Superimposed Vertical Loads.** The minimum period during which forms and supports for concrete structures must remain in place are listed in Table 602-A and are defined either by the "Time" or the "Cylinder Strength" requirements.

***Table 602-A***

***Minimum Requirements for Removal of Formwork, Placement of***

***Superimposed Vertical Loads, and Placement of Backfill***

| *Structural Element* | *Removal of Formwork* | | *Placing Superimposed Vertical Dead Loads** | | *Placement of Backfill* | |
|---|---|---|---|---|---|---|
| | *Time (days)* | *Strength (%f $N_c$)* | *Time (days)* | *Strength (%f $N_c$)* | *Time (days)* | *Strength (%f $N_c$)* |
| Arch [Span # 65' (20 m)](B.F.) | 3 | 40 | 21 | 95 | 21 | 95 |
| Arch (Span # 65' (20 m)](S.F.) | 2 | 30 | | | | |
| Concrete Beam (B.F.) | 7 | 60 | 12 | 80 | n/a | n/a |
| Concrete Beam (S.F.) | 2 | 30 | | | | |
| Slab [Span # 10' (3 m)] and Diaphragms | 2 | 30 | 14 | 85 | n/a | n/a |
| Slab [Span > 10' (3 m)] | 5 | 50 | | | | |
| Piers/Columns | 2 | 30 | 5 | 50 | n/a | n/a |
| Pile Cap and Pier Cap | 5 | 50 | 7 | 60 | 5 | 50 |
| Footing | 2 | 30 | 3 | 40 | 2 | 30 |
| Cast-In- Place Concrete Piles | n/a | n/a | 5 | 50 | n/a | n/a |
| Subfoundation Concrete | 1 | 20 | 2 | 30 | 1 | 20 |
| Retaining Wall, Headwall, and Wingwall | 2 | 30 | 2 | 30 | 21 | 95 |
| Parapet Wall, Curb, and Backwall | 1 | 20 | 1 | 20 | 5 | 50 |
| Abutment Wall, Rigid Frame Wall, and Box Culvert Wall | 2 | 30 | 5 | 50 | 21 | 95 |

B.F. - Bottom Form S.F. - Side Form

* Examples of such are as follows; placement of parapet on slab, placement of wall on footing, placement of beam on pier cap, etc...

During cold weather [less than 40 ºF (4 ºC)] and hot weather [greater than 85 ºF (30 ºC)] forms for vertical surfaces shall remain in place for a minimum of five days. Forms may be removed prior to five days only if the concrete is protected in a manner suitable to the Engineer. The Contractor shall submit a protection plan for the concrete in writing to the Engineer and have it approved by the Engineer prior to form removal.

Upon removal of the forms or protection, surface cavity repairs, finishing, and curing of the exposed areas shall begin immediately.

Except during weather conditions noted above, the forms for rubbed surfaces shall be removed no longer than 48 hours after placing of the concrete.

In using Table 602-A, consideration shall be given to the location and character of the structure, the weather and other conditions influencing the setting of the concrete, and the material used in the mix. The use of retarder or special cements shall require special attention.

The minimum required strength of concrete listed in Table 602-A shall be used as a guide when and where field operations are controlled by the "Cylinder Strength" and approved by the Engineer. If the Contractor intends to begin removing forms as soon as the concrete has reached the minimum required strength of Table 602-A, the Contractor shall give the Engineer written notice, 48 hours prior to pouring the concrete, that the start of form removal will depend on the "Cylinder Strength" requirements.

When the Contractor desires cylinder testing other than seven- and 28-day testing, it shall be the responsibility of the Contractor to supply the molds and to make the cylinders under the supervision of the Engineer. The molds for structural concrete shall be 4" (100 mm) by 8" (200 mm) and shall meet the requirements of *Cylinder Molds* under AASHTO T 23. If the Contractor requests cylinder testing other than seven- and 28-day testing and does not perform the testing, the Department's Materials and Research Section will perform the testing; however, the Contractor shall be charged for the testing and a credit will be given to the Department.

Cylinders cast for the specific use as "Cylinder Strength" testing for form removal shall be cured in the field under the same conditions as the concrete they represent. It shall also be the responsibility of the Contractor to ensure that the seven- and 28-day cylinders are cured for the first 24 to 48 hours in an environment to provide satisfactory moisture and temperature control as per AASHTO T 23.

Department personnel will test the cylinders made by the Contractor to determine concrete strength at the time the Contractor wishes to remove forms or place loads on the concrete.

These "Strength" and "Time" requirements listed in Table 602-A are intended only for the construction operations indicated and shall not apply to the use of equipment or other live loads on the structure. Stockpiling of materials and the use of unauthorized equipment on the structure will not be permitted.

Truck mixers, dump trucks, cranes, and other heavy construction equipment will be not permitted to cross or to be parked on a completed structure, nor will the structure be opened to construction or public traffic until so authorized by the Engineer. The "Cylinder Strength" must have attained full design compressive strength ($f'_c$), and concrete must be at least ten days old before this authorization will be given.

All forms shall be removed whether above or below the ground line or water level.

Methods of form removal likely to cause overstressing of the concrete shall not be used. Forms and their supports shall not be removed without the approval of the Engineer.

Supports shall be removed in such a manner as to permit the concrete to take, uniformly and gradually, the stress due to its own weight.

Falsework under all spans shall be completely released before forms are constructed and concrete is placed for parapets and curb.

Forms for footings constructed within cofferdams or cribs may be left in place, when, in the opinion of the Engineer, their removal would endanger the safety of the cofferdam or crib, and when the forms so left intact will not be exposed to view in the finished structure.

The interior forms supporting the roadway slab of box girder type structures shall be supported on wales or similar supports fastened, as nearly as possible, to the top of side walls, and may be left in place. The interior forms supporting the roadway slab shall not be shored to or supported on the box girders bottom slab.

As soon as forms are removed, all form ties used for holding the forms in place shall be removed and the holes, depressions, or small voids thus made which show upon the removal of the forms, shall be filled with cement mortar mixed in the same proportions as that which was used in the body of the work.

The work shall be so planned and executed that form removal and specified finishing is performed within the required limits. Otherwise, subsequent placement of concrete in other parts of the structure or structures shall be ordered stopped.

Concrete which is to be exposed to sea water or tidal brackish water shall be placed in the dry unless otherwise directed. Sea water or brackish water shall not come in direct contact with concrete prior to the times indicated in Table 602-B unless otherwise directed.

***Table 602-B***

***Requirements for the Removal of Formwork for Concrete***

***in Contact with Sea Water or Brackish Water***

| *Water Salinity*<br><br>*(ppm dissolved salts)* | *Days to Elapse*<br><br>*Prior to Salt Water Contact* |
|---|---|
| 0 to 10 000 | Normal Curing |
| 10 000 to 20 000 | 15 |
| 20 000 to 30 000 | 25 |
| over 30 000 | 30 |

**602.20 Bridge Decks.**

a. *Permanent Steel Bridge Deck Formwork*. Permanent steel bridge deck forms for concrete deck slabs of bridges shall be used when shown on the Plans.

1. *Design.* The steel forms shall be designed on the basis of dead load of the form, reinforcement, and plastic concrete plus 50 lb/ft$^5$ (2.4 kPa) for construction loads. The unit working stress in the steel sheet shall be not more than 72.5% of the specified minimum yield strength of the material furnished, but not to exceed 36,000 lb/in$^5$ (250 MPa).

   Deflection under the weight of the forms, the plastic concrete, and the reinforcement shall not exceed 1/180 of the form span or 2" (13 mm), whichever is less, however, the deadload design weight for this minimum deflection shall be no less than 120 lb/ft$^5$ (5.75 kPa) total.

   The permissible form camber shall be based on the actual dead load condition. Camber shall not be used to compensate for deflection in excess of the foregoing limits.

   The design span of the form sheets shall be the clear span of the form plus 2" (50 mm) measured parallel to the form flutes. Physical design properties shall be computed in accordance with requirements of the AISI Specification for the Design of Cold-Formed Steel Structural Members.

   All deck reinforcement shall have a minimum concrete cover of 2" (50 mm) for the top mat of steel and 1" (25 mm) for the bottom mat unless otherwise specified on the Plans.

   The plan dimensions of both layers of primary deck reinforcement from the top surface of the concrete deck shall be maintained.

   Permanent steel bridge deck forms shall not be considered as lateral bracing for compression flanges of supporting structural members.

   Permanent steel bridge deck forms shall not be used in panels where longitudinal deck expansion joints are located between stringers.

Welding shall not be permitted to flanges in tension or to structural steel bridge elements fabricated from non-weldable grades of steel.

Fabricators' shop and erection drawings shall be submitted to the Engineer for approval. These drawings shall indicate the grade of steel, the physical and section properties for all permanent steel bridge deck form sheets, and a clear indication of locations where the forms are supported by steel beam flanges subject to tensile stresses.

2. *Construction.* All forms shall be installed in accordance with approved fabrication and erection drawings.

   Form sheets shall not be permitted to rest directly on the top of the stringer or floor beam flanges. Sheets shall be securely fastened to form supports and shall have a minimum bearing length of 1" (25 mm) at each end. Form supports shall be placed in direct contact with the flange of stringer or floor beam. All attachments shall be made by permissible welds, bolts, clips, or other approved means. However, welding of form supports to flanges of steels not considered weldable and to portions of a flange subject to tensile stresses shall not be permitted. Welding and welds shall be in accordance with the provisions of AWS D2.0 pertaining to fillet welds, except that 1/8" (3 mm) fillet welds will be permitted.

   Any permanently exposed form metal where the galvanized coating has been damaged shall be thoroughly cleaned, wire brushed, and painted with one coat of organic zinc paint, to the satisfaction of the Engineer. Minor heat discoloration in areas of welds need not be touched up.

   The direction lapping of forms shall be consistent with the direction of concrete placement.

3. *Inspection.* The Contractor's method of construction should be carefully observed during all phases of the construction of the bridge deck slab. These phases include installation of the metal forms; location and fastening of the reinforcement; composition of concrete items; mixing procedures; concrete placement and vibration; and finishing of the bridge deck. Should the Engineer determine that the procedures used during the placement of the concrete warrant inspection of the underside of the deck, the Contractor shall remove at least one section of the forms at a location and time selected by the Engineer for each span in the Contract. This should be done as soon after placing the concrete as practicable in order to provide visual evidence that the concrete mix and the Contractor's procedures are obtaining the desired results. An additional section shall be removed if the Engineer determines that there has been any change in the concrete mix or in the Contractor's procedures warranting additional inspection.

   After the deck concrete has been in place for a minimum period of two days, the concrete shall be tested for soundness and bonding to the forms by sounding with a hammer as directed by the Engineer. If areas of doubtful soundness are disclosed by this procedure, the Contractor will be required to remove the forms from such areas for visual inspection after the pour has attained adequate strength.

   At locations where sections of the forms are removed, the Contractor will not be required to replace the forms, but the adjacent metal forms and support shall be repaired to present a neat appearance and ensure their satisfactory retention. As soon as the form is removed, the concrete surfaces will be examined for cavities, honeycombing and other defects. If irregularities are found, and it is determined by the Engineer that these irregularities do not justify rejection of the work, the concrete shall be repaired as the Engineer may direct and shall be given an ordinary surface finish, in accordance with the Contract. If the concrete where the form is removed is unsatisfactory, additional forms, as necessary, shall be removed to inspect and repair the slab, and the Contractor's methods of construction shall be modified as required to obtain satisfactory concrete in the slab. All unsatisfactory concrete shall be removed and repaired as directed by the Engineer.

   The amount of sounding and form removal may be moderated, at the Engineer's discretion, after a substantial amount of slab has been constructed and inspected, if the Contractor's methods of construction and the result of the inspections as outlined above indicate that sound concrete is being obtained throughout the slabs.

The Contractor shall provide all facilities as are reasonably required for the safe and convenient conduct of the Engineer's inspection procedures

b. *Concrete Work.* A smooth, durable riding surface of uniform texture, true to the required grade and cross-section, shall be obtained on all bridge decks.

Concrete shall be placed in accordance with the Contract. Particular emphasis should be placed on proper vibration of the concrete to avoid honeycomb and voids, especially at construction joints, expansion joints, and valleys and ends of form sheets. Pouring sequences, procedures, and mixes shall be approved by the Engineer.

The placing of concrete in bridge decks will not be permitted until the Contractor has satisfied the Engineer that it has adequate personnel and equipment to deliver, place, spread, finish, and cure a minimum of 20 yd; (15 $m^3$) of concrete per hour, that experienced finishing machine operators and concrete finishers are employed to finish the deck, and that weather protective equipment and all necessary finishing tools and equipment are on hand at the site of the work and in satisfactory condition for use.

Prior to any deck concreting, a "pre-pour" conference will be held with the Contractor and representatives of the Department in attendance. At this time, the Contractor shall present its plan and procedures for deck construction.

Supports for screeds or finishing machines shall be completely in place and firmly secured before placing of concrete will be permitted. Supports shall be set to elevations necessary to obtain a bridge deck true to the required grade and cross-section, with allowance being made for anticipated settlement. Supports shall be of a type and shall be so installed that no springing or deflection will occur under the weight of the finishing equipment, and shall be so located that finishing equipment may operate without interruption over the entire bridge deck being furnished.

Immediately prior to placing bridge deck concrete, the Contractor shall check all falsework and shall make all necessary adjustments. Suitable means such as telltales shall be provided by the Contractor to permit ready measurement by the Engineer of deflection as it occurs.

On continuous steel beam or girder spans, the order of casting shall be as shown on the Plans. On simple spans, and for any section between construction joints for continuous spans, the concrete in the floor slab may be placed by beginning at the end and working along the roadway or by beginning at the side and working across the roadway. The screeding method used shall have been approved by the Engineer.

Screeding operations shall include a mechanical screed of the power-actuated oscillating type. Vibrating screeds will not be permitted unless specifically approved by the Engineer. The screed shall be sufficiently rigid and easy to control in order to provide substantially uniform treatment over the deck surface. Screeds shall be of the transverse type and shall be of sufficient weight to strike off the surface at the specified grade. Longitudinal type screeds shall not be used without prior written approval from the Engineer.

When the longitudinal type screed is used, the over-all length shall be such as to screed independently supported spans up to and including 80' (24 m). In no case shall the length of the screed be less than the full length of the span for spans less than 80' (24 m). When using the longitudinal type screed on independently supported spans exceeding 80' (24 m) in length with a screed length less than the full length of the span, the center half of the span, preferably more, shall be completed first and then the remaining portions completed. Bulkheads or other substantial supports for the screed shall be placed over the abutments and/or piers and at the terminal point of placements within the span. The surface of a previously placed section shall not be used as a bearing area for the screed track until control cylinders have attained a minimum strength of 0.6 $f'_c$ where $f'_c$ is the design minimum laboratory compressive strength as specified on the Plans.

When a transverse screed is used, the screed shall be of a sufficient size to finish the full width of the deck between curbs or parapets unless a longitudinal joint in the deck is specified. In this case, the portion on either side of the joint shall be placed and finished separately. The wheels of the screed shall bear on temporary rails which shall be adequately supported on and directly above the main structural members or on form supports. In case of continuous spans, the form supports shall be fully supported by the principal structural members supporting the deck. The rails shall be sufficiently rigid and strong to permit the screed to finish the surface of the deck within the requirements of this Section. If the rails are placed within the roadway area, they shall be elevated a sufficient distance above the deck to permit the simultaneous finishing by hand of any portion not finished by the screed. Rail supports extending above the roadway surface shall be fabricated and installed in such a manner as to permit their removal to at least 2" (50 mm) below the top surface of the deck slab. Any portion of the rail support to remain in

the deck concrete shall be fusion bonded epoxy coated. Where rail supports are placed in that portion of the deck under the curbs or parapets, the supports shall be so placed that they will be at least 2" (50 mm) from the face of the curb parapet walls or outside edge of the slab.

During the screeding operation, an adequate supply of concrete shall be kept ahead of the screed and a slight excess shall be maintained immediately in front of the screed. Workers will not be permitted to walk on the concrete after screeding. The Contractor shall provide a sufficient number of work bridges or other suitable platforms to provide adequate access to the work, and so that screeding, finishing, and curing operations can progress without delay. The work bridge shall be supported outside the limits of the concreting.

An adequate supply of suitable coverings which will protect the surface of the freshly placed bridge deck from rain shall be readily available at the site of the work.

Where the concrete in the deck of a continuous beam or girder span group cannot be placed in one operation, the location of construction joints and sequence of placement shall be in accordance with an approved placement schedule. After the initial placement has been made in any one group of a continuous span, no further placement shall be made until all previously placed concrete in the deck of that group has been in place for at least three days or until the cylinder strength is at least 0.5 $f'_c$.

Roadway surfaces of bridge decks and approach slabs shall be wet cured, as soon as possible, according to Subsection 602.18 (a). Membrane curing compound shall not be used on bridge decks and approach slabs except when cold weather dictates its use. The Engineer will determine when cold weather requires membrane curing. When required, membrane curing compound shall be applied in accordance with the requirements of Subsection 501.11 immediately after the finishing operation. Within 24 hours, the roadway surfaces shall also be covered with waterproof covers as set forth in Subsection 501.13. The waterproof covers shall remain in place for not less than seven days. Extreme care shall be taken to protect adjacent reinforcing steel from the membrane curing compound.

The Contractor shall test the fresh concrete deck surface with a 10' (3.048 m) straightedge, and the Contractor shall re-screed the deck surface as many times as is necessary to ensure a smooth riding surface. The straightedge shall be held in successive positions at the edges, quarter points, and on the centerline, parallel thereto and in contact with the surface. Advancement along the deck shall be in successive stages of not more than one-half the length of the straightedge. The surface shall also be checked transversely at the ends, quarter points, and center of the span. Areas showing high spots or depressions of more than 1/8" (3 mm) in 10' (3.048m) in the longitudinal direction and 1/4" (6 mm) in 10' (3.048 m) in the transverse direction shall be struck off or filled with freshly mixed concrete as the case may be. Special attention shall be given to ensure that the surface across joints meets the requirements for smoothness.

After the deck has cured the surface will be tested using either a straightedge, a rolling straightedge, or a California-type profilograph. If surface testing using a California-type profilograph is required, testing and corrective work shall conform to the requirements of Subsection 501.17. Surface testing the cured concrete with a straightedge or rolling straightedge will be performed as described above for fresh concrete. High spots or depressions of more than 1/8" (3 mm) in 10' (3.048 m) in the longitudinal direction and 1/4" (6 mm) in 10' (3.048 m) in the transverse direction shall be corrected by patching and/or grinding at no cost to the Department. Any cracking which occurs prior to opening to traffic shall be sealed or repaired in a manner approved by the Engineer at no cost to the Department. The deck shall also be sounded and any delaminated areas shall be removed and replaced in a manner approved by the Engineer at no cost to the Department.

C. *Surface Texture.* All bridge deck surfaces shall be textured either by mechanical grooving or by manual texturing. Unless otherwise noted in the Contract, texturing will be done by mechanical grooving.

1. *Mechanical Grooving.* Bridge deck and approach slab surfaces shall be textured by first dragging a fabric over the final screeded concrete and then by sawing transverse grooves in the cured concrete. After final screeding of the surface, the Contractor shall drag multiple-ply damp fabric over the surface to provide a gritty texture. After the bridge deck or approach slab has been cured and attained 75% of the 28-day design compressive strength, the Contractor shall saw uniformly pronounced grooves transverse to the centerlines.

   Grooves shall be sawn approximately 1/10" (2.5 mm) wide, 1/8 to 3/16" (3 to 5 mm) deep, and on 12" (38 mm) (nominal) centers. Grooves shall terminate 18 " 1" (450 " 25 mm) from the face of the

parapet. Grooves shall not be sawn any closer than 2" (50 mm) nor further than 3" (75 mm) from the edge of any joint. When the width of the cutting head on the grooving machine is such that grooves can not be practically sawn to within the required tolerance for a skewed transverse joint, grooving shall begin on the side of the deck having the acute angle corner, and nominal spacing of the grooves at the starting point shall be 12" (38 mm) on center. In the event that a single pass of the grooving machine can not be made across the width of the bridge or approach slab, then the mating ends of subsequent passes shall not overlap previous grooves nor leave more than 1" (25 mm) of surface ungrooved.

For bridge lengths over 300' (90 m), a randomly spaced groove pattern shall be used. The random spacing shall be from 1 3/8" (35 mm) centers to 1 5/8" (40 mm) centers, as determined by the Engineer.

Removal of all debris, including slurry, resulting from the grooving operations shall be continuous. Surfaces must be immediately left in a washed and clean condition, free of all slipperiness from the slurry. All debris and surplus material removed from the grooving operations shall be deposited in a truck, or other conveyance, and disposed.

2. *Manual Texturing.* When specified, after the concrete has been consolidated and struck off and before the concrete becomes non-plastic, the surface shall then receive a transverse texture. Texturing shall be done by use of a wire broom having a single row of tines or a finned float having a single row of fins. The broom or float shall produce transverse grooves that are spaced at intervals of approximately 2 to 3/4" (13 to 19 mm) center to center. The grooves in the hardened surface shall be approximately 0.08 to 0.12" (2 to 5 mm) in width and 0.15 to 0.25" (3 to 6 mm) in depth. The grooving shall be applied to the entire deck surface except that area within 18" (450 mm) from the face of curb.

**602.21 Holes.** Drainage openings and weep holes shall be constructed in the manner and at locations indicated on the Plans, or as directed. No deduction in the computed volume of concrete masonry, except for openings in pipe headwalls, will be made.

**602.22 Placing Pipe and Conduits.** Pipes and conduits which are to be encased in the concrete, as shown on the Plans, shall be placed by the Contractor during construction. Such pipes and conduits shall be furnished and placed by the Contractor unless otherwise stated on the Plans.

**602.23 Placing Anchors, Bolts, Grills, and Other Embedments.** Anchors, bolts, grills, and other embedments, which are to be placed in the concrete as indicated on the Plans, shall be furnished and placed by the Contractor during construction.

**602.24 Night Lighting.** The Contractor shall be responsible for submitting to the Engineer a lighting plan showing the locations and aiming of the floodlights. After the Engineer has reviewed the lighting plan, the Contractor shall conduct a test run of the floodlighting system at the proposed construction area prior to the proposed use. The lighting system will be checked for proper aiming and positioning, level and uniformity of illuminance, and any hazard to maintenance of traffic. The floodlighting system shall be capable of being adjusted to avoid glare that may blind the traffic and mobile enough to allow for proper aiming and positioning to provide the desired results. Any adjustments required by the Engineer shall be corrected by the Contractor. No nighttime construction shall begin until the floodlighting system with the lighting plan has been approved in writing by the Engineer.

Lamps for floodlights shall be either tungsten halogen, mercury vapor, metal halide, or high pressure sodium. The floodlighting system shall provide maximum uniformity of light, producing a level of illuminance of 20 average horizontal ft-c (215 lx) over the construction work area. The Contractor shall supply a photometer to test the illuminance level during the test run. The Contractor shall submit to the Engineer, not less than 30 days prior to the test, the type, style, or catalog number of the photometer to be used for the test. At the same time, the Contractor shall include a written certification that the equipment was calibrated by a testing agency approved by the Engineer not more than 60 days prior to the date when such tests are to be performed. The test is to be performed by the Contractor and witnessed by the Engineer. The photometer is to be of the latest available type and cosine corrected. The angle between the beam center of the flood light and vertical shall not exceed 60 degrees. The mounting height of the floodlights shall be not less than 30' (9 m) above any traveled roadway which is directly influenced by the floodlights. Otherwise, the floodlights shall be not less than 20' (6 m) above the work area.

The Contractor shall exercise reasonable care to avoid any interruptions of the lighting system during working operations. If a portable generator is used, it shall have a rated capacity large enough not to create flickering during work operations. An emergency backup system shall be available on the job site if a portable generator is used. The fuel tank for the generator shall be of sufficient capacity to permit operation at full load for at least 12 hours.

All materials involved in this Subsection shall remain the property of the Contractor.

**602.25 Defective Work.** Any defective work discovered after the forms have been removed shall be immediately removed and replaced. If the surface of the concrete is bulged or uneven, or shows honeycombing that cannot be repaired satisfactorily, the entire section shall be removed and replaced.

Concrete which fails to reach full 28-day design strength ($f'_c$) will be considered defective concrete. If the concrete is determined to not be structurally adequate by the Engineer, then it shall be removed and replaced. If the concrete is determined to be structurally adequate by the Engineer and the concrete can remain in place, the Contractor shall have the following options:

1. Accept the low strength concrete test results and all remedial action as described in the below categories or;

2. Challenge the low strength concrete test result by coring the area which the test cylinders represent.

If the Contractor elects to take cores to challenge the cylinder strength results, it shall be the Contractor's responsibility to obtain two cores (one for the Department and one for the Contractor) at the location determined by the Engineer. After the cores have been obtained, the concrete cores shall be tested for compressive strength in the as-cored moisture condition and the Contractor's core testing results shall be provided to the Department no later than five working days after verbal notification that the cylinder strength test results were substandard.

If the average of the core testing results (Department and Contractor) are greater than or equal to the specified 28-day design strength, the Contractor shall be paid the full bid price for the concrete in question. If the average core testing results are less than the specified strength, the remedial action as described in the following categories will be required:

| | |
|---|---|
| *Category A:* | *0 to 250 psi (0 to 1.66 MPa) below 28-day Design Strength* |
| | No repair required, full payment as specified in Subsection 602.27. |
| *Category B:* | *251 to 500 psi (1.67 to 3.33 MPa) below 28-day Design Strength* |
| | Prorated payment as specified in Subsection 602.27. |
| *Category C:* | *501 to 1000 psi (3.34 to 6.66 MPa) below 28-day Design Strength* |
| | Prorated payment as specified in Subsection 602.27 plus the application of a protective waterproofing that is approved by the Department's Materials and Research Section. The coating shall be clear and shall only be applied to the pour area that the core represents. |
| *Category D:* | *1000 psi (6.67 MPa) or greater below 28-day Design Strength* |
| | Strengthen area of low strength concrete as approved by the Engineer at no cost to the Department. |

If the difference in strength between the Department's results and the Contractor's independent test laboratory results are greater than 501 psi (3.34 MPa), the core testing results will be considered void and the prorated payment as specified in Subsection 602.27 will be applied to the concrete in question based upon the field-cast cylinders.

**602.26 Method of Measurement.** The quantity of portland cement concrete will be measured as the number of cubic yards (cubic meters) of concrete placed and accepted. The volume will be computed using the dimensions shown on the Plans, or as ordered in writing. The quantity of concrete in floor slabs will be computed from the dimensions shown on the Plans with no allowance for form deflection or stay-in-place form corrugations. No deduction in the computed volume of portland cement concrete will be made for pipes with outside diameters of 12" (300 mm) or less, conduits, anchors, bolts, and scuppers. The quantity of concrete in deck slabs will be computed from design deck thickness.

- Floodlighting will not be measured.
- The quantity of grooving will not be measured.

**602.27 Basis of Payment.**

a. *General.* The quantity of portland cement concrete will be paid for at the Contract unit price per cubic yard (cubic meter). Price and payment will constitute full compensation for furnishing all materials, forms, and falsework; for cold weather protection; for removal of bridge deck forms to allow visual inspection of areas of doubtful soundness and bonding of concrete; for construction of drainage openings and weepholes; for furnishing and placing pipes and conduits; for furnishing and placing anchors, bolts, and scuppers; for furnishing and maintaining light plants and lighting equipment; for grooving and removing all debris or for manual texturing; and for furnishing all equipment, tools, labor, and incidentals required to complete the work.

b. *Price Adjustment for Low Strength Concrete.* Prorated payment for concrete as specified in Subsection 602.25 shall be calculated as shown in the following equation:

$$\text{Prorated Payment} = \frac{\text{Low Compressive Strength Concrete}}{\text{Specified Compressive Strength}} \times (\text{Quantity of Concrete}^{*}) \times (\text{Bid Price}^{**})$$

* The quantity for which the low compressive strength results represent.

** Item bid price; not material cost.

**SECTION 603 BAR REINFORCEMENT**

**603.01 Description.** This work consists of furnishing and placing bar reinforcement.

**MATERIALS.**

**603.02 Bar Reinforcement.** Bar reinforcement shall conform to the requirements of Section 824.

**603.03 Working Drawings.** Working drawings shall be submitted in accordance with Subsection 105.04. In addition, the Contractor shall submit complete, detailed bar lists and bending diagrams for all bar reinforcement to be furnished. The Contractor shall be responsible for checking all bar lists and details shown on the Plans for accuracy as to the quantity, size, length, and dimensions before ordering bars from its lists. Bar lists may be prepared on sheets of a size and type that are the supplier's standard.

**CONSTRUCTION METHODS.**

**603.04 Storage.** Bar reinforcement shall be stored on wooden platforms or other hard, clean surfaces, and shall be placed under cover. The Contractor shall not permit bar reinforcement to be in direct contact with soil.

**603.05 Placing.** All bar reinforcement shall be free from dirt, oil, paint, grease, mill scale, and loose or thick rust. When bending is required, it shall be accurately accomplished without the use of heat. Bar reinforcement with cracks or splits at the bends will be rejected.

All bar reinforcement shall be placed in the position shown on the Plans and shall be held in position by wiring at bar intersections. The bar reinforcement shall be securely held so that it will not be displaced during the placing and consolidating of the concrete. In bridge decks, bar reinforcement shall be tied at all intersections. For all other construction, bar reinforcement shall be tied at all intersections except where bar spacing is less than 12" (300 mm) in both directions, in which case alternate intersections shall be tied. The use of pebbles, bricks, broken stone, metal or wooden blocks, or other unapproved material for blocking is prohibited.

Chairs and metal supports in contact with the forms shall be plastic or rubber tipped. Epoxy or plastic coated chairs fabricated with turned-up legs are acceptable. Precast concrete may be used to provide the required vertical clearance between bar reinforcement and the ground in foundations.

**603.06 Welding.** Welding of bar reinforcement shall be performed only where detailed on the Plans or the approved working drawings, or if authorized in writing. Welding shall conform to ANSI/AWS D1.4. The workmanship shall not result in any burning or reduction in section of the bar reinforcement. The Contractor shall obtain the Engineer's approval for all welding methods and results.

**603.07 Splicing Bar Reinforcement.** All bar reinforcement shall be furnished in the full lengths indicated on the Plans unless otherwise permitted. Splicing of bars, except where shown on the Plans, will not be permitted without written approval. Splices shall be staggered as far as possible. Unless otherwise shown on the Plans, bars shall be spliced in accordance with the AASHTO Standard Specifications for Highway Bridges. In lapped splices, the bars shall be placed and wired in such a manner as to maintain the minimum distance to the surface of the concrete shown on the Plans. Lapped splices shall not be used for No. 14 (No. 43) and No. 18 (No. 57) bars. Connecting bars mechanically or by welding shall be done only if detailed on the Plans or authorized in writing by the Engineer.

**603.08 Method of Measurement.** The quantity of bar reinforcement will be measured by determining the theoretical weight, in pounds (kilograms), of the steel placed as shown on the Plans and accepted. For the purpose of computing the theoretical weight of bar reinforcement, the following table shall be used:

***Table 603-A***

***Deformed Metric Bar Designation Numbers and Unit Weights***

| *Bar Size Designation*<br><br>*US Customary (Metric)* | *Unit Weight lb/ft (kg/m)* |
|---|---|
| #3 (#10) | 0.376 (0.560) |
| #4 (#13) | 0.668 (0.994) |
| #5 (#16) | 1.043 (1.552) |
| #6 (#19) | 1.502 (2.235) |
| #7 (#22) | 2.044 (3.042) |
| #8 (#25) | 2.670 (3.973) |
| #9 (#29) | 3.400 (5.060) |
| #10 (#32) | 4,303 (6.404) |
| #11 (#36) | 5.313 (7.907) |
| #14 (#43) | 7.65 (11.38) |
| #18 (#57) | 13.60 (20.24) |

**603.09 Basis of Payment.** The quantity of bar reinforcement will be paid for at the Contract unit price per pound (kilogram), based upon the metric designation. Price and payment will constitute full compensation for furnishing and placing all materials, including clips, wire, chairs, and other material used for fastening the bar reinforcement in place, for banding and splicing, and for all labor, equipment, tools, and incidentals required to complete the work.

**SECTION 604 BAR REINFORCEMENT, EPOXY COATED**

**604.01 Description.** This work consists of furnishing and placing epoxy coated bar reinforcement.

**MATERIALS.**

**604.02 Bar Reinforcement.** Epoxy coated bar reinforcement shall conform to the requirements of Section 824.

**604.03 Repair Material.** The Contractor shall furnish a certification from the coating manufacturer that the repair material is compatible with the coating material.

**604.04 Working Drawings.** Working drawings shall be submitted in accordance with Subsection 603.03. In addition, the working drawings shall indicate to the fabricator and coater that the spacing between bands around bundled bars shall not exceed 13' (4 m).

**CONSTRUCTION METHODS.**

**604.05 Storage and Protection.** Epoxy coated bar reinforcement shall be stored on wooden or padded supports that will keep the Epoxy coated bars that have been exposed to sunlight for 90 days shall be covered. This requirement includes partially embedded bars. The cover shall be opaque to block sunlight and shall be placed to allow air circulation around the bars.

In order to protect the coated bar reinforcement from damage during movement, the Contractor shall ensure that bands used to secure rebar in bundles are spaced no more than 13' (4 m) apart. The Contractor shall also use padded or non-metallic slings and padded straps to handle bundled bars. Bundles of epoxy coated bars shall be lifted by spreader bars or multiple supports from a platform bridge that will prevent bar-to-bar abrasion from sags. Bundles shall not be picked up by the banding material. Bars and bundles shall not be dropped, dragged, or driven over. The Contractor may propose alternate precautionary measures for the Engineer's approval.

**604.06 Placing.**

a. Bridge Decks. The bottom layer of bar reinforcement in bridge decks shall be supported from the forms on continuous type bar supports placed parallel to the beams and spaced with the lines of supports, as measured between beam centers, at approximately the 1/4 and 3/4 points for beam spacing less than 9' (2.7 m) and at approximately the 1/6, 1/2, and 5/6 points for beam spacing 9' (2.7 m) and over. Additional individual chairs may be required outside the fascia beam to securely support the bar reinforcement along and near the fascia. The continuous type bar supports and individual chairs in contact with epoxy coated bars shall be either epoxy or plastic coated, as approved. The Contractor may propose other devices for the Engineer's approval. Coated chairs fabricated with straight legs shall also be equipped with plastic or rubber tips. Coated chairs fabricated with turned-up legs do not require tips

   The upper layer of bar reinforcement in bridge decks shall be supported with rows of approved, continuous, steel bar supports consisting of a minimum of three longitudinal wires acting as spacers at the proper height. The longitudinal wires shall be securely tied to the structural steel, stud shear developers, or other structural components at intervals not greater than 5' (1.5 m) along each beam or girder. Tie-downs shall consist of loops of 12 gage (2.7 mm) coated wire, or equivalent devices meeting the approval of the Engineer.

b. *Other Structures.* The method of placement for structures other than bridge decks shall conform to the requirements of Subsection 603.05. The wire, chairs, and metal supports in contact with epoxy coated bars shall, at the Contractor's option, be either epoxy or plastic coated. Epoxy coated bar reinforcement shall not come in contact with any materials to be embedded in the concrete which are not epoxy or plastic coated.

**604.07 Splicing Reinforcement.** Splicing shall conform to the requirements of Subsection 603.07.

**604.08 Repair of Epoxy Coating.** If, in the opinion of the Engineer, the coating on bar reinforcement has been damaged, the damaged bar will be rejected and shall be properly repaired or replaced.

Repair material shall be compatible with the coating, inert in concrete, and supplied by the epoxy resin manufacturer. The material shall be suitable for repairing areas of the coating that have been damaged and shall be applied at the point of application, fabrication, or installation, as may be required. Sheared ends and other cut or exposed areas shall be repaired promptly before detrimental oxidation occurs. These areas shall be clean and free from all surface contaminants.

The sum of the damaged areas of coating in each 1 yd (1 m) of length of bar reinforcement shall not exceed 6% of the surface area in that 1 yd (1 m) length of bar. All visible damage of the epoxy coating shall be repaired. The total bar surface area covered by patching material shall not exceed 2%.

**604.09 Method of Measurement.** The quantity of epoxy coated bar reinforcement will be measured according to Subsection 603.08.

**604.10 Basis of Payment.** The quantity of epoxy coated bar reinforcement will be paid for at the Contract unit price per pound (kilogram) based upon metric designation as shown in the Table 603-A. Price and payment will constitute full compensation for furnishing and placing all materials, including the epoxy resin, clips, wire, chairs, and other material used for fastening the bar reinforcement in place; for preparing the bar reinforcement surfaces for epoxy coating; for applying the epoxy coating; for bending, splicing, and repairing; and for all labor, equipment, tools, and incidentals required to complete the work.

## SECTION 605 STEEL STRUCTURES

**605.01 Description.** This work consists of furnishing, field fabricating, erecting, and painting structural steel for bolted and welded construction.

This work also consists of recoating a portion of or the entire existing steel structure.

**605.02 Materials.** Materials for steel structures shall conform to the following Subsections:

| | |
|---|---|
| Coatings | 820.02 |
| Structural Steel | 826.02 |
| Fasteners | 826.03 |
| Shear Connectors | 826.04 |
| Forgings and Castings | 826.05 |
| Bearing Materials | 826.06 |
| Galvanizing | 826.07 |
| Sheet Zinc | 826.08 |

**605.03 Storage of Materials.** Structural material shall be stored above the ground on platforms, skids, or other supports. It shall be kept free from dirt, grease, and other foreign matter, and shall be protected as far as practicable from corrosion.

### FABRICATION.

**605.04 Straightening Material.** Rolled material, before being laid out or worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal. Sharp kinks and bends shall be cause for rejection of the material.

**605.05 Finish.** Portions of the work exposed to view shall be finished neatly. Shearing, flame cutting, and chipping shall be done carefully and accurately and result in square and true edges.

**605.06 Holes.**

1. *High Strength Bolts.* All holes for high strength bolts shall be either punched or reamed or drilled. When there are more than five layers of metal to be bolted or when any of the material is thicker than 3/4" (19 mm) for carbon steel, or 5/8" (16 mm) for high-strength steel, all holes shall be either subpunched or subdrilled 3/16" (5 mm) smaller than the diameter of the bolts. After preliminary assembling, the holes shall be reamed 1/16" (2 mm) larger or drilled from the solid to 1/16" (2 mm) larger than the diameter of the bolts.

   Material forming parts of a member composed of not more than five layers of metal may be punched 1/16" (2 mm) larger than the diameter of the bolts whenever the thickness of the metal is not greater than 3/4" (19 mm) for structural steel or 5/8" (16 mm) for high-strength steel.

2. *Ribbed Bolts, Turned Bolts, or other Approved Bearing Type Bolts.* All holes for ribbed bolts, turned bolts, or other approved bearing type bolts shall be either subpunched or subdrilled 3/16" (5 mm) smaller than the diameter of the bolt and reamed assembled to a steel template or, after assembling, drilled from the solid at the option of the fabricator. In any case the finished holes shall provide a driving fit as specified on the Plans or in the Special Provisions.

**605.07 Punched Holes.** The diameter of the die shall not exceed the diameter of the punch by more than 1/16" (2 mm). All holes to be enlarged to admit the bolts must be reamed. Holes must be cut clean without torn or ragged edges. Poor matching of holes will be cause for rejection.

**605.08 Reamed or Drilled Bolt Holes.** Reamed or drilled holes shall be cylindrical and perpendicular to the member. Where practicable, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Poor matching of holes will be cause for rejection. Reaming and drilling shall be done with twist drills. If required by the Engineer, assembled members shall be taken apart for removal of burrs caused by drilling. Connecting members requiring reamed or drilled holes shall be assembled and securely held while being reamed or drilled and shall be match-marked before disassembling.

**605.09 Subpunching or Subdrilling and Reaming Field Connections.** Unless otherwise specified in the Special Provisions or on the Plans, holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched or subdrilled and reamed while assembled to a steel template. Drilling full size holes, in lieu of assembly reaming or template reaming undersized holes, will be permitted upon approval of the procedures by the Engineer.

All holes for floor beam and stringer field end connections shall be subpunched or subdrilled and reamed to a steel template or reamed while assembled. Reaming or drilling full size field connection holes through a steel template shall be done after the template has been located with respect to position and angle and firmly bolted in place. Templates used for reaming matching members, or the opposite faces of a single member, shall be exact duplicates. Templates used for connections on like parts or members shall be located so that the parts or members are duplicates and require no match-marking.

If additional subpunching or subdrilling and reaming is required, it shall be specified in the Special Provisions or on the Plans.

**605.10 Accuracy of Punched, Subpunched, and Drilled Holes.** All holes punched full size, subpunched, or subdrilled shall be so accurately punched that after assembling and before any reaming is done, cylindrical pins 1/8" (3 mm) smaller in diameter than the size of the punched, subpunched, and subdrilled holes may be entered perpendicular to the face of the member without drifting, in at least 75% of the contiguous holes in the same plane. If this requirement is not fulfilled, the members will be rejected. If any hole will not pass a pin 3/16" (5 mm) smaller in diameter than the size of the punched hole, this will be cause for rejection.

**605.11 Accuracy of Reamed and Drilled Holes.** When holes are reamed or drilled, 85% of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1/32" (1 mm) between adjacent thicknesses of metal.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. The centerlines shall be used in locating accurately the template from the milled or scribed ends of the members.

**605.12 Fitting for Bolting.** Surfaces of metal in contact shall be cleaned before assembling. The members shall be assembled, well pinned, and firmly drawn together with bolts before reaming is commenced. Assembled members shall be taken apart, if necessary, for the removal of burrs and shavings produced by the reaming operation. All members shall be free from twists, bends, and other deformations.

**605.13 Drifting of Holes.** The drifting during assembling shall only be to bring the members into position for bolting. The drifting shall not enlarge the holes or distort the metal. All holes to be enlarged must be reamed.

**605.14 Connections Using Non-High-Strength Bolts.** Non-high-strength bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A bolts of ASTM A 307. Bolted connections shall be used only as indicated by the Plans or Special Provisions. Bolts shall have single, self-locking nuts or double nuts unless otherwise shown on the Plans or in the Special Provisions. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis.

a. *Unfinished Bolts.* Unfinished bolts shall be furnished unless other types are specified.

b. *Turned Bolts.* The surface finish of the body of turned bolts shall meet the ANSI B 46.1 roughness rating value of 125 (3.2 µm). Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Holes for turned bolts shall be carefully reamed for the bolts furnished to provide for a light driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut.

c. *Ribbed Bolts.* The body of ribbed bolts shall be of any approved form with continuous longitudinal ribs. The diameter of the body measured on a circle through the points of the ribs shall be 5/64" (2 mm) greater than the nominal diameter specified for the bolts.

   Ribbed bolts shall be furnished with round heads conforming to ANSI/ASME B18.5.2.2M unless otherwise specified. Nuts shall be hexagonal. The nuts shall be recessed or installed using washers of suitable thickness. Ribbed bolts shall make a driving fit with the holes. The hardness of the ribs shall be such that the ribs do not mash down enough to permit the bolts to turn in the holes during tightening. If for any reason the bolt twists before drawing tight, the holes shall be carefully reamed and an oversized bolt used as a replacement.

**605.15 High Strength Bolts.** This Subsection covers the assembly of structural joints using AASHTO M 164 (M 164M) high-strength carbon steel bolts and AASHTO M 253 (M 253M) quenched and tempered alloy steel bolts or equivalent fasteners, tightened to a high tension. Holes for high-strength bolt connections shall conform to the requirements of Subsections 605.06, 605.07, and 605.08.

a. *Bolts, Nuts, and Washers.* Bolts manufactured to AASHTO M 164 (M 164M) shall be marked on the top of the head with three radial lines and the symbol **A325** (**A 325M)**.

   All galvanized nuts shall be lubricated with a water soluble lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation. Nuts shall be marked according to the requirements of ASTM A563 (A 563M).

   Bolts, nuts, and washers shall be kept protected from the weather or any other adverse environments. Weathered or rusted fasteners or fasteners which have lost their lubricant or protective coating will be rejected for use.

   Bolt and nut dimensions shall conform to the dimensions shown in Table 605-A.

**Table 605-A**

**Bolt and Nut Dimensions, U.S. Customary**

| Heavy Hex Structural Bolts (Inches) | | | | Heavy Hex Nuts (Inches) | |
|---|---|---|---|---|---|
| Nominal Bolt Diameter, D | Width Across Flats, F | Height, H | Thread Length | Width Across Flats, W | Height, H |
| 1/2 | 7/8 | 5/16 | 1 | 7/8 | 31/64 |
| 5/8 | 1 1/6 | 25/64 | 1 1/4 | 1 1/6 | 39/64 |
| 3/4 | 1 1/4 | 15/32 | 1 3/8 | 1 1/4 | 47/64 |
| 7/8 | 1 7/16 | 35/64 | 1 1/2 | 1 7/16 | 55/64 |
| 1 | 1 5/8 | 39/64 | 1 3/4 | 1 5/8 | 63/64 |
| 1 1/8 | 1 13/16 | 11/16 | 2 | 1 13/16 | 1 7/64 |
| 1 1/4 | 2 | 25/32 | 2 | 2 | 1 7/32 |
| 1 3/8 | 2 3/16 | 27/32 | 2 1/4 | 2 3/16 | 1 11/32 |
| 1 1/2 | 2 3/8 | 15/16 | 2 1/4 | 2 3/8 | 1 15/32 |

***Table 605-A***

***Bolt and Nut Dimensions Metric***

| *Nominal Bolt Diameter and Thread Pitch* [1] | *Heavy Hexagon Structural Bolt Dimensions* [1] *(mm)* | | | | | | *Nut Dimensions* [2] *(mm)* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Body Diameter (D)* | | *Width Across Flats (S)* | | *Head Height (K)* | | *Width Across Flats (S)* | | *Thickness (M)* | |
| | *max.* | *min.* | *max.* | *min.* | *max.* | *min.* | *max.* | *min.* | *max.* | *min.* |
| M16 H 2 | 16.70 | 15.30 | 27.00 | 26.16 | 10.75 | 9.25 | 27.00 | 26.16 | 17.10 | 16.40 |
| M20 H 2.5 | 20.84 | 19.16 | 34.00 | 33.00 | 13.40 | 11.60 | 34.00 | 33.00 | 20.70 | 19.40 |
| M22 H 2.5 | 22.84 | 21.16 | 36.00 | 35.00 | 14.90 | 13.10 | 36.00 | 35.00 | 23.60 | 22.30 |
| M24 H 3 | 24.84 | 23.16 | 41.00 | 40.00 | 15.90 | 14.10 | 41.00 | 40.00 | 24.20 | 22.90 |
| M27 H 3 | 27.84 | 26.16 | 46.00 | 45.00 | 17.90 | 16.10 | 46.00 | 45.00 | 27.60 | 26.30 |
| M30 H 3.5 | 30.84 | 29.16 | 50.00 | 49.00 | 19.75 | 17.65 | 50.00 | 49.00 | 30.70 | 29.10 |
| M36 H 4 | 37.00 | 35.00 | 60.00 | 58.80 | 23.55 | 21.45 | 60.00 | 58.80 | 36.60 | 35.00 |

Note 1: From ANSI B18.2.3.7M - 1979. Pitch = the distance in millimeters from the crest of one thread to the crest of the next thread.

Note 2: From ANSI B18.2.4.6M - 1979.

b. *Bolted Members.* The slope of surfaces of bolted members in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted members shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material.

When assembled, all faying surfaces including the outside surfaces adjacent to the bolt heads, nuts, or washers shall be free of scale, except for tight mill scale. The faying surfaces shall also be free of dirt, loose scale, burrs, other foreign material, and other defects that would prevent solid seating of the members.

c. *Surface Preparation of Contact Surfaces.* Contact surfaces of high strength bolted connections which are considered within friction-type joints shall be free of oil, paint, lacquer, rust inhibitor, or galvanizing unless specifically modified by the Plans or Special Provisions.

d. *Bolt Tension.* During installation each fastener shall be tightened to provide a tension which is greater than 70% of the tensile strength given in AASHTO M164 for A325 (AASHTO M 164M for A 325M) bolts and between 70% of the minimum and maximum tensile strength given in AASHTO M253 for A490 (AASHTO M 253M for A 490M) bolts.

**Table 605-B, US Customary**

**Minimum Bolt Tension (pounds)**

| Bolt Size (in.) | AASHTO M164 (ASTM A325) Bolts | AASHTO M253 (ASTM A490) Bolts |
|---|---|---|
| 1/2 | 12,050 | 14,900 |
| 5/8 | 19,200 | 23,700 |
| 3/4 | 28,400 | 35,100 |
| 7/8 | 39,250 | 48,500 |
| 1 | 51,500 | 63,600 |
| 1 1/8 | 56,450 | 80,100 |
| 1 1/4 | 71,700 | 101,800 |
| 1 3/8 | 85,450 | 121,300 |
| 1 1/2 | 104,000 | 147,500 |

***Table 605-B Metric***

***Minimum Bolt Tension [1], kilonewtons***

| *Nominal Bolt Diameter and Thread Pitch* | *AASHTO M 164M* | *AASHTO M 253M* | |
|---|---|---|---|
| | | *min.* | *max.* |
| M16 H 2 | 91 | 114 | 132 |
| M20 H 2.5 | 142 | 179 | 206 |
| M22 H 2.5 | 176 | 221 | 255 |
| M24 H 3 | 205 | 257 | 297 |
| M27 H 3 | 267 | 334 | 386 |
| M30 H 3.5 | 326 | 408 | 471 |
| M36 H 4 | 475 | 595 | 686 |

Note 1: Equal to 70% of specified minimum tensile strength of bolts.

Threaded bolts shall be tightened by the turn-of-nut method. If required because of bolt-entering and wrench-operation clearances, tightening may be done by turning the bolt while the nut is prevented from rotating. Impact wrenches, if used, shall be of adequate capacity and supplied with sufficient air to perform the required tightening of each bolt in approximately ten seconds.

e. *Washers.* All fasteners shall have a hardened washer under the element (nut or bolt head) turned in tightening. Hardened washers shall be used under both the head and nut regardless of the element turned when using AASHTO M253 (ASTM 490) [AASHTO M 253M (ASTM A 490M)] bolts, if the material against which it bears has a specified yield strength of less than 40,000 psi (276 MPa).

Where an outer face of the bolted members has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth, beveled washer shall be used to compensate for the lack of parallelism.

f. *Calibrated Wrench Testing.* To check the correct calibration of a wrench, the Skidmore-Wilhelm Bolt Tension Calibrator or equivalent tension measuring device shall be furnished.

g. *Turn-of-Nut Tightening.* When the turn-of-nut method is used to provide the bolt tension specified under (d) above, there shall first be enough bolts brought to a "snug tight" condition to ensure that all members of the connection are brought into full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a construction worker using an ordinary spud wrench. Following this initial operation, bolts shall be placed in all remaining holes in the connection and brought to snug tightness. All bolts in the connection shall then be tightened by the applicable amount of nut rotation specified in Table 605-C. Tightening shall progress systematically from the most rigid part of the connection to its free edges. During this operation there shall be no rotation of the element not turned by the wrench.

h. *Tightening by Use of a Load Indicating Fastener System.* Tightening by this means is permitted provided it can be demonstrated, by an accurate, direct measurement procedure, that the bolt has been tightened in accordance with Table 605-C. Tightening shall be by methods and procedures approved by the Engineer.

***Table 605-C***

***Nut Rotation from Snug Tight Condition*** [1]

| *Bolt Length,measured from underside of head to extreme end of point* | *Both faces normal to bolt axis* | *One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)* | *Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)* |
|---|---|---|---|
| Up to and including 4 diameters | 1/3 turn | 1/2 turn | 2/3 turn |
| Over 4 diameters but not exceeding 8 diameters | 1/2 turn | 2/3 turn | 5/6 turn |
| Over 8 diameters but not exceeding 12 diameters [2] | 2/3 turn | 5/6 turn | 1 turn |

Note 1: Nut rotation is relative to the bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be ''30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be ''45 degrees.

Note 2: No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedures when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

i. *Inspection.*

1. The Engineer will determine when the requirements of (3)b. and (3)c. below are met. When the calibrated-wrench method of tightening is used, the Engineer will have full opportunity to witness the calibration tests prescribed under (f) above.
2. The Engineer will observe the installation and tightening of bolts to determine if the selected tightening procedure is properly used and will determine when all bolts are tightened.
3. The following inspection procedure shall be used unless a more extensive or different inspection procedure is specified:

    a. Either the Engineer will or the Contractor in the presence of the Engineer, at the Engineer's option, shall perform the inspection using an inspection wrench. The inspection wrench may be either a torque wrench or a power wrench that can be accurately adjusted in accordance with the requirements under (f) above.

    b. Three bolts of the same grade, size*, and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the element turned. (* Length may be any length representative of bolts used in the structure.)

    c. When the inspection wrench is a torque wrench, each of the three bolts shall be tightened in the calibration device by any convenient means to the minimum tension specified for its size under (d) above. The inspection wrench shall then

be applied to the tightened bolt, and the torque necessary to turn the nut or head five degrees [approximately 1" (25 mm) at a 12" (300 mm) radius] in the tightening direction shall be determined. The average torque measured in the tests of the three bolts shall be taken as the job inspecting torque to be used as specified in (3)e. below.

d. When the inspection wrench is a power wrench, it shall be adjusted so that it tightens each of the three bolts to a tension at least 5% but not more than 10% greater than the minimum tension specified for its size under (d) above. This tension setting of the power wrench shall be taken as the job inspecting torque to be used in the manner specified in (3)e. below.

e. Bolts represented by the three-bolt sample that have been tightened in the structure shall be inspected by applying in the tightening direction, the inspection wrench to its job inspecting torque on 10% of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt is turned by this application of the job inspecting torque, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection. All bolts whose nut or head is turned by the job inspecting torque shall be tightened and re-inspected. Alternatively, the Contractor has the option to retighten all of the bolts in the connection and then resubmit the connection for inspection.

**605.16 Plate Cut Edges.**

1. *Edge Planing.* Sheared edges of plates more than 5/8" (16 mm) in thickness and carrying calculated stress shall be planed, milled, ground, or thermal cut to a depth of 3" (6 mm). Re-entrant cuts shall be filleted to a minimum radius of 3/4" (19 mm) before cutting.

*Visual Inspection and Repair of Plate Cut Edges.* In the repair and determination of limits of internal defects visually observed on sheared or flame-cut edges and caused by entrapping slag or refractory, deoxidation products, gas pockets, or blow holes, the amount of metal removed shall be the minimum necessary to remove the defect or to determine that the permissible unit is not exceeded. Plate edges may be at any angle with respect to the rolling direction. All repairs of defects made by welding shall conform to the applicable provisions of ANSI/AASHTO/AWS D1.5, *Bridge Welding Code* as modified in this Section. The limits of acceptability and the repair of visually observed edge defects in plates 4" (100 mm) and under in thickness shall be in accordance with Table 605-D.***Table 605-D***

***Required Repairs for Discontinuity***

| *Description of Discontinuity* | *Repair Required* |
|---|---|
| Any discontinuity 1" (25 mm) in length or less and 1/8" (3 mm) maximum depth. | None; need not be explored. |
| Any discontinuity over 1" (25 mm) in length and 1/8" (3 mm) maximum depth. | None; depth should be explored by random spot grinding |
| Any discontinuity over 1" (25 mm) in length with depth over 1/8" (3 mm) but not greater than 3" (6 mm) . | Remove discontinuity; need not fill area with weld material. |
| Any discontinuity over 1" (25 mm) length with depth over 3" (6 mm) but not greater than 1" (25 mm). | Completely remove and weld. Aggregate length of welding shall not exceed 20% of plate edge length being repaired. |
| Any discontinuity over 1" (25 mm) in length with depth greater than 1" (25 mm). | Subject to approval by the Engineer. Repair to be made in accordance with Section 3.2 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges. |

Note 1: The length of defect is the visible long dimension on the plate cut edge, and the depth is the distance that the defect extends into the plate from the cut edge.

Note 2: This table does not apply to fracture critical members.

Steel plate, bar, or shapes containing any discontinuity, regardless of length or depth, will not be permitted for use in any member or component in a tension area.

**605.17 Welding and Oxygen Cutting.** All welding and oxygen cutting shall conform to the requirements of Subsection 826.12.

**605.18 Joints.** Abutting joints in compression members and girder flanges, and in tension members where so specified on the drawings, shall be faced and brought to an even bearing. Wheel joints are not faced and the opening shall not exceed 3" (6 mm).

**605.19 End Connection Angles.** Floorbeams, stringers, and girders having end connection angles shall be built to the exact length shown on the Plans measured between the heels of the connection angles with a permissible tolerance of +0 to -1/16" (+0 to -2 mm). Where continuity is required, end connections shall be faced. The thickness of the connection angles shall be not less than 3/8" (10 mm) and not less than that shown on the detail drawings, after facing.

**605.20 Web Plates.** For girders having no cover plates and not encased in concrete, the top edge of the web plate shall not extend above the backs of the flange angles and shall not be more than 1/8" (3 mm) below at any point. Any portion of the plate projecting beyond the angles shall be chipped flush with the backs of the angles.

At web splices, the clearance between the ends of the web plates shall not exceed 3/8" (10 mm). The clearance at the top and bottom ends of the web splice plates shall not exceed 3" (6 mm).

**605.21 Bent Plates.** Cold-bent, load-carrying, rolled-steel plates shall conform to the following:

1. They shall be taken from the stock plates so that the bend-line will be at right angles to the direction of rolling.
2. The radius of bends shall be such that no cracking of the plate occurs. Generally accepted minimum radii, measured to the concave face of the metal, are shown in Table 605-E:

***Table 605-E***

***Minimum Radii for Cold Bent Steel Plates***

***radii and t (thickness) in millimeters***

| *All Grades of Structural Steel in this Section* | Up to 2" (13 mm) | Over 2" (13 mm) to 1" (25 mm) | Over 1" (25mm) to 12" (38 mm) | Over 12" (38 mm) to 22" (64 mm) | Over 22" (64 mm) |
|---|---|---|---|---|---|
| *Bend Radius* | 2t | 2.5t | 3t | 3.5t | 4t |

Note: Low alloy steel in thickness over 2" (13 mm) may require hot bending for small radii. If a shorter radius is essential, the plates shall be bent hot at a temperature not greater than 1150 ºF (620 ºC). Hot-bent plates shall conform to (a) above.

3. Before bending, the corners of the plates shall be rounded to a radius of 1/16" (2 mm) throughout that portion of the plates at which the bending is to occur.

**605.22 Eyebars.** Pin holes may be flame-cut at least 2" (50 mm) smaller in diameter than the finished pin diameter. All eyebars that are to be placed side by side in the structure shall be securely fastened together so that they will be placed on the pin and bored at both ends while clamped. Eyebars shall be packed and match-marked for shipment and erection. All identifying marks shall be stamped with steel stencils on the edge of one head of each member after fabrication is completed so that the markings will be visible when the bars are nested in place on the structure. The eyebars shall be straight and free from twists, and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not exceed 1/16" to a foot (1 in 200 mm).

The edges of eyebars lying between the transverse centerline of their pin shall be cut simultaneously with two mechanically operated torches abreast of each other guided by a substantial template in such a manner as to prevent distortion of the plates.

**605.23 Testing Requirements.** Testing of fabricated structural members shall be according to Subsection 826.26.

**FIELD ERECTION.**

**605.24 Erection of Structure.** The Contractor shall set the steel according to the lines and elevations as provided in the Contract, remove the temporary construction, and do all the work required to complete the bridge or bridges as covered by the Contract, all in accordance with the Plans and this Section.

**605.25 Erection Material.** The Contractor shall provide the falsework and all tools, machinery, and appliances, including drift pins and fitting-up bolts, necessary to complete the work.

**605.26 Handling and Storing Fabricated Materials.** Stored material shall be placed on skids above the ground. It shall be kept clean and shall be properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent permanent deflections.

**605.27 Falsework.** The Contractor shall engage a Professional Engineer registered in Delaware to design the falsework separately for steel structures and for necessary changes in existing steel structures on the Project. The Professional Engineer's signature and seal shall be affixed to the working drawings. Working falsework drawings shall be submitted in accordance with Subsection 105.04. The falsework shall be properly designed, constructed, and maintained for the loads that it will carry. It is the Contractor's responsibility to obtain approval of the working drawings from the Department prior to the construction of the falsework. Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility. After placement of the falsework, the Contractor's Professional Engineer shall certify that the falsework system has been assembled according to the approved falsework drawing prior to placing loads on the falsework.

**605.28 Methods and Equipment.** Before starting the work of erection, the Contractor shall inform the Engineer as to the method of erection it proposes to follow and the number and type of equipment it proposes to use. The Contractor's methods and equipment shall be subject to the approval of the Engineer. The Engineer's approval does not relieve the Contractor of its responsibility for the safe performance of the work or from carrying out the work in full accordance with the Plans and the requirements of this Section. No work shall be done until the Engineer's approval has been obtained.

**605.29 Anchorages.**

1. *Bearings.* Bridge bearings shall be set level in the exact position indicated and shall have full and even bearing on the masonry. Prior to assembly in place, the steel surface bearing on the self-lubricating bearing plate shall be thoroughly lubricated with additional antioxidant lubricant furnished by the manufacturer.

   The sliding surface shall be planed parallel to the movement of the spans.
2. *Anchor Bolts.* Anchor bolts, when required, including hex nuts and washers, shall conform to the requirements of AASHTO M 314 unless otherwise specified on the Plans. The exposed portion of the anchor bolt shall be either galvanized or painted, unless otherwise specified.

   When the anchor bolt passes through the sole plate, the nut is to be 3" (6 mm) clear. The threads shall be burred at face of nut. Anchor bolts shall be swedged and may be cast-in-place or grouted in preformed (sleeved or drilled) holes. If the Contractor elects to drill, it shall not cut through the bar reinforcement in the masonry. All slots and holes in the masonry plates surrounding the anchor bolts shall be filled with an approved, non-hardening caulking compound or elastic joint sealer.

**605.30 Straightening Bent Material.** The straightening of plates, angles, other shapes, and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fractures or other injuries. Distorted members shall be straightened using mechanical means or, if approved by the Engineer, using a limited amount of localized heat. The temperature of the heated area shall not exceed 1150 EF (620 EC) (a dull red) as monitored by temperature indicating crayons, liquids, or bimetal thermometers. Members to be heat-straightened shall be substantially free of stress and external forces, except stresses resulting from the mechanical means used in conjunction with the application of heat.

Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture.

**605.31 Assembling Steel.** The members shall be accurately assembled as shown on the Plans and all match-marks shall be followed. The material shall be carefully handled so that no members are bent, broken, or otherwise damaged. Hammering which injures or distorts the members shall not be done. Bearing surfaces and surfaces in permanent contact shall be cleaned before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so to give the trusses proper camber. The blocking shall be left in place until the tension chord splices are fully bolted and all other truss connections are pinned and bolted. Permanent bolts in splices of butt joints of compression members and permanent bolts in railings shall not be tightened until the span has been swung. One-half of the holes in splices and field connections shall be filled with bolts and cylindrical erection pins (half bolts and half pins) before bolting with high-strength bolts. All splices and connections during erection shall have three-fourths of the holes filled.

Filling-up bolts shall be of the same nominal diameter as the high strength bolts. Cylindrical erection pins shall be 1/32" (1 mm) larger.

**605.32 Pin Connections.** Pilot and driving nuts shall be used for driving pins. They shall be furnished by the Contractor. Pins shall be driven so that the members take full bearing on them. Pin nuts shall be securely fastened, and the threads shall be burred at the face of the nut using a pointed tool.

**605.33 Misfits.** The correction of minor misfits involving harmless amounts of reaming, cutting, and chipping will be considered a legitimate part of the erection. However, all errors in the shop fabrication, or deformations resulting from handling and transportation, that prevent the proper assembly and fitting up of members by the moderate use of drift pins, or by a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the inspector to obtain approval of the proposed correction method. All corrections shall be made in the inspector's presence.

**605.34 Cleaning and Restoration.** Upon completion of the erection and before final acceptance, the Contractor shall remove all falsework, excavated or useless materials, rubbish, and temporary buildings. The Contractor shall also replace or renew any damaged fences, restore in an acceptable manner all property, both public and private, damaged during the

prosecution of this work, and leave the structure site and adjacent highway in a neat and presentable condition satisfactory to the Engineer. All excavated material or falsework placed in the stream channel during construction shall be removed by the Contractor before final acceptance.

**FIELD PAINTING.**

**605.35 Field Painting.** All structural steel members, railings, fascia, downspouts, and other miscellaneous steel items that have been previously painted shall be cleaned, and primed and painted by applying two full coats of paint, the intermediate coat and the finish coat. The coating system to be used shall meet the requirements of moisture-cured urethane system as specified in Subsection 820.02.

**605.36 Surface Preparation.** Surfaces identified to be painted shall be cleaned in the following manner:

1. Surfaces specified to be recoated shall be cleaned to bare metal in accordance with SSPC-SP 11.

   The perimeter or edge of intact paint adjoining the cleaned surface shall be feathered back, and the adjoining paint shall be tightly adhered. Ragged edges on intact paint will not be allowed. Adherence will only be considered satisfactory if the adjoining remaining paint is smoothly feathered back and cannot be removed by lifting with a dull putty knife. After power tool cleaning operations are completed, all residue generated by the cleaning work shall be removed by vacuuming using HEPA filtered vacuums.

   Surfaces shall be accepted by visual comparison to a prepared Project standard. The Contractor shall prepare the Project standard by power tool cleaning a representative area on the structure that is being prepared for painting. The prepared standard shall generally conform to SSPC-Vis 3, E SP 11, F SP 11, and G SP 11, as applicable, and shall be approved by the Engineer before the start of general cleaning work. At least one standard shall be prepared for each structure that is being specified for cleaning. More than one standard may be necessary if the cleaned steel differs significantly from the photographic standards due to surface conditions or other factors. Each standard shall be at least 12 by 12" (300 by 300 mm) in size and shall be located in an area of the structure that is accessible to and approved by the Engineer.

   The Contractor shall protect the Project standard from corrosion and contamination throughout the duration of work. Protection shall be by applying a clear coat of polyurethane, or other means. At the completion of cleaning work, the Project standard shall be re-cleaned and painted in accordance with this Section. If in the opinion of the Engineer the Project standard becomes deteriorated, or otherwise ineffective, it shall be re-established in accordance with this Subsection.

2. Surfaces specified to be over-coated shall be solvent cleaned after water blasting.

**605.37 Painting.**

a. *Manufacturer's Instructions.* At least five working days prior to the start of work, the Contractor shall provide the Engineer with one copy of the paint manufacturer's current Technical Data and Material Safety Data Sheets for the paint materials being furnished. Instructions, suggestions, and precautions contained in the data sheets shall be followed to the extent that they do not contradict the provisions of this Section. In the case of a contradiction, the more stringent requirements shall be followed.
b. *Specifications and Inspection Equipment.* Prior to the start of and throughout the duration of work, the Contractor shall supply the Engineer with the following:

   1. One bound copy each of the SSPC surface preparation specifications, SSPC-SP 1 and SSPC-SP 11;
   2. One bound copy of the SSPC pictorial standard, SSPC-Vis 3;
   3. One bound copy of the SSPC paint application specification, SSPC-PA 2;
   4. One air thermometer, pocket type, ranging from 0 to 200 EF (-17 to 93 EC);
   5. One surface thermometer, ranging from 0 to 300 EF (-18 to 149 EC); and
   6. One magnetic dry film thickness gage, Type 2 (fixed probe);

c. *Atmospheric Conditions.* Painting shall not be performed unless all of the following conditions are met:

1. The receiving surface is clean and free of rust back, condensation, and visible moisture. Rustback occurs when freshly exposed bare steel is exposed to conditions of high humidity, moisture, or a corrosive atmosphere. The time interval from blast cleaning to rust back varies from minutes to weeks depending on the environment.
2. The receiving surface and ambient air temperature are as recommended by the paint manufacturer, except that in no case shall painting work be performed when the surface and ambient temperatures are less than 36 or greater than 100 EF (2 or greater than 38 EC).
3. *Mixing Paint.* All paints shall be thoroughly mixed with mechanical mixers in accordance with the manufacturer's recommendations.
4. *Solvent Restrictions.* The Contractor may thin the paint only with approved manufacturer's thinner. Thinning will be allowed only in strict accordance with manufacturer's recommendations and State VOC regulations. Unauthorized use of solvents shall result in re-cleaning and repainting of the surface in accordance with this Section.
5. *Paint Application.* Paint coatings may be applied using brush, roller, or spray methods unless prohibited by the Contract. When spray painting is prohibited, paint shall be applied using brushes or rollers only.

   Stripe painting with primer will be required on the following surfaces cleaned to bare metal. All welds, rivets, bolts, nuts, and edges of plates, angles, lattice, pieces, or other shapes, and corners and crevices shall be "striped" with primer before the general prime coat is applied. All stripe painting shall be performed using a brush only. No other method of paint application will be allowed for stripe painting.

   Complete protection against paint spatter, spillage, overspray, wind blown paint, or similar releases of paint shall be provided. Covers, tarps, mesh, and similar materials shall be placed around the work area to protect public and private property; pedestrian, vehicular, marine, or other traffic; all portions of the bridge, highway appurtenances, waterways, and similar surrounding areas; and property upon, beneath, or adjacent to the structure.

d. *Number of Coats.* Areas cleaned to bare metal and specified to be recoated shall be painted with one coat of primer. After the primer has dried, all surfaces shall be painted with two full coats of paint: the intermediate coat and the finish coat.

e. *Film Thickness.* Paint shall be applied in sufficient quantity to produce the minimum dry film thickness specified in Section 820 for the type of paint specified.

f. *Painting Schedule.* Primer shall be applied on the same day of the cleaning operation and before rust back occurs. Failure to apply primer to a cleaned surface within eight hours shall result in recleaning the surface in accordance with this Section.

   The intermediate coat of paint shall be applied to the receiving surface within 14 days of the application of the previous coating (primer), or within the manufacturer's recommended schedule for recoating, whichever is less.

   The finish coat of paint shall be applied to the receiving surface within 14 days of the application of the previous (intermediate) coating, or within the manufacturer's recommended schedule for recoating, whichever is less.

   Areas failing to meet the specified minimum dry film thickness shall be recoated with the same type of paint to produce at least the total dry film thickness required. Paint applied containing thinners, paint applied to contaminated surfaces, and paint applied contrary to this Section shall result in recleaning and repainting the surface. The work of recleaning and repainting, if required, shall be done by the Contractor to the satisfaction of the Engineer.

g. *Material Storage.* Paint in storage shall be protected from damage and maintained between 40 and 85 ºF (5 and 29 ºC). Paint not used before the expiration shall be immediately removed from the Project.

**605.38 Painting of Galvanized Steel.** All galvanized surfaces (downspouts, etc.) shall be painted with a moisture-cured aluminum paint that is designed to adhere to galvanized steel surfaces.

**605.39 Stenciling Requirement.** At the completion of the painting work, the completion date (month and year) and the bridge number, shall be stenciled on the structure in 3" (75 mm) high numbers. The paint used for this marking shall be the same as the topcoat except the color shall be black. The numbers shall be stenciled on the outside of each fascia beam at the approaching traffic end of the structure, on a location designated by the Engineer. The Contractor shall paint the month and year of the existing stenciling after the existing stenciling area is cleaned and painted if so required in case of partial painting of the structure.